
THE CAMEL FOR THE SAHARA DESERT
THE CAMPBELL METHOD FOR THE AMERICAN DESERT

H. W. CAMPBELL

Campbell's 1907 Soil Culture Manual

A Complete Guide to Scientific Agriculture as Adapted to the Semi-Arid Regions.

BY

H. W. CAMPBELL.

The proper fitting of the Soil for the Conservation and Control of Moisture and the Development of Soil Fertility; How Moisture Moves in the Soil by Capillary Attraction, Percolation and Evaporation; the Relation of Water and Air to Plant Growth, and how this may be Regulated by Cultivation. : : : : : : : : : : : : :

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CHAPTER I.

INTRODUCTION.

Agricultural industry is undergoing in these opening years of the Twentieth century a most wonderful development in the direction of that perfection of method and practical application of scientific principles which has been the hope and inspiration of thoughtful students of agriculture through ages.

That which is being wrought out by workers, by students, by thinkers, by investigators in all branches of agriculture—in plant breeding, in domestic animal industry, in crop diversification, in planting, and harvesting, and marketing—goes directly to the final solution of the essential problems connected with production.

Farming methods of the past century were those of preceding years; the methods of our century are to be those of the next thousand years.

This does not mean that our forefathers did not know anything about farming, nor that what they did was all wrong, nor that they failed to solve the problems of their day and age. It does not mean we are on the verge of revolution and are about to overturn old methods and adopt entirely new ones all round. But with the more varied needs of mankind as civilization becomes more complicated, and the proportionate narrowing of our fields as we approach the limit of tillable area, the new and complicated problems are to be met only by the putting together of many heads and the accumulation of much

wisdom. The strides we are making just now are beyond those of other days. We are in position to take advantage of the accumulation of evidence and to discover the truth that shall endure.

The reader will not find in the pages of this Soil Culture Manual a universal guide to success in farming. But he will find something here that will be of immense value to him if he but has the patience and industry to master the principles and is willing to give a fair trial to the methods which are here described for the treatment of soils. It is presented with a confidence born of years of investigation and experiment, and of success in many seasons of adverse conditions spread out over many states with soil and climate as different as it is possible to have.

This Soil Culture Manual has to do with just one subject, or rather one branch of agriculture, but it so happens that this lies at the very foundation of all agriculture. Production is the end and aim of all farming. Production is possible only where soil conditions are right, for no matter what may be the climate or the extent of cultivation, there cannot be crops if there is not fertility available in the soil. Available fertility may exist, under most favored conditions, where there has been no cultivation; but it is more often true that fertility comes from conditions brought about by cultivation done intelligently.

This handling of the soil with a view to the development of available fertility is Scientific Soil culture.

It is my purpose to present in this Manual the results of years of labor in this field. I desire to treat a complicated subject with plainness and frankness. Here is material for a discourse filled with scientific terms, but I shall try to be so plain that everyone may know all about it. I shall give something of the history of the develop-

ment of what has come to be known in a dozen or more states as the Campbell system of soil culture; shall tell why and how I came to make the investigations which led up to this; shall discuss freely the principles which lie at the foundation; shall tell what has been accomplished and what may be expected; and I shall give here instructions as to how to apply these principles as nearly complete as possible.

In previous editions of the Manual, and in various other publications and in public addresses, commencing a dozen years ago, I have insisted that science in soil culture and the more perfect adaptation of scientific methods to farming would result in doubling the crops in the great semi-arid belt of America. In later years I have made the statement still stronger and have declared, to the amazement of some of the doubting ones, that crops have not been one-fourth what they should have been in this region. It is because I have had faith in this region and have been confident that crops could be made as certain here as elsewhere, that I have pursued investigations, often under the most discouraging conditions and in the face of fierce opposition, and it is in the hope that I may convince others, not a few but thousands, that I publish this Manual.

While the investigations which have resulted in the development of this system of soil culture have been carried on in the semi-arid belt, or that region where the rainfall is too small for successful farming in the ordinary way, it should be understood at the outset that the principles are applicable anywhere and in any climate, and that even where there is an excess of moisture, those who make use of the system will achieve results of great value. The difficulties to be overcome by the farmer in assuring

good crops are so pronounced in this semi-arid region that it seems specially fitted for development of the very highest type of agricultural science; but everywhere the problems are much the same, and having shown the way to success here, the way will be much easier elsewhere. There is hardly a section of the United States that can be said to be free from the danger of crop failure by reason of the irregular distribution of the rainfall. The season of drouth, or weeks of dryness perhaps sandwiched between other weeks of excessive rainfall, are common to all regions. In showing how to overcome the danger which is ever present in the semi-arid region we have also shown how to avoid the danger which comes occasionally in any farming country. The system therefore is of universal application. If in discussing it solely in relation to the problems of the semi-arid region I seem to ignore this larger truth, it is not because it is not well understood.

I also admonish the reader not to take fright of the subject because it appears to be ponderous and uninteresting. The term, "scientific soil culture," may seem heavy, but I assure you that when once you have grasped the principles here made use of, the study will become the most fascinating imaginable. Other branches of agriculture are attractive to intelligent persons. Consider what has been achieved in stock breeding, in adaptation of breeds to certain purposes, in bringing about perfection in the domestic animals; then observe what has been done in the production of the improved varieties of vegetables and fruits, and in creation of marvelously beautiful flowers; all the result of applying the genius of man to intelligent direction of the resources of nature—and in the special line of scientific treatment of the soil to secure

a variety of results there is just as much opportunity for original research. The flower garden does not contain all the wonders

I present this Manual to the public with greater confidence than its predecessors, because the evidence has been accumulating that the secret of success in the semi-arid region lies in proper fitting of the soil. To the evidence which has come directly from the numerous experimental farms that have been handled under my personal direction has been added the testimony of scores of farmers who have followed more or less imperfectly the directions contained in previous editions of the Soil Culture Manual. Along with this is the more important fact that everywhere in the states most affected there has come to be general recognition of the vital truths of the system and there is such a unamimous interest in the whole subject that it is no longer necessary to beg for a hearing. I have greater confidence also from the fact that all the time I have been learning more and more about the subject, have been developing my own ideas and dissipating my own doubts, until I feel sure that what I am here to present has far greater merit than anvthing which has preceded. I have not done with experiments nor have I satisfied myself that I have reached the very best possible results, but I do know that I have gone a long way toward perfecting a system through which the forces of nature may be made to serve man at all times.

It is not intended that this Soil Culture Manual shall contain any simple code of imperative rules to govern every act of the farmer in his culture of the soil. The nature of the subject forbids this. What must be done is to give the inquirer a clear statement of general principles, with simple directions for applying the same under

many varied conditions, and to explain the reason for doing certain things—then to leave it to the intelligent direction of the farmer to do the rest. These general principles relate to soil physics, to the character of the soil, the texture of the soil, the movement of moisture in the soil, the development of soil fertility or those elements essential to plant growth, and what can be done and must be done by cultivation to affect the quantity and quality of the crop. One who comprehends clearly these principles and labors with the knowledge that is in him, will find the way to profitable agriculture.

There can be no universal rule for the cultivation of the soil. Conditions are so different that there must be variation. Everyone knows that drainage is necessary to some soils in some climates. It is not so well understood that where the rainfall is insufficient there can be conservation of the moisture by cultivation. Neither is it generally known that by and through cultivation of the soil there is brought about great changes in the physical condition so that soils having but little available fertility may be strengthened and others burdened with plant elements are modified. Some important general rules may be applied, however, in the semi-arid region, so that they may be followed with assurance that there will be conservation of moisture and development of plant elements and the consequent growth of crops equal to those grown in the more humid regions of the country.

It ought not to be difficult for any one to recall facts and incidents which have come under his personal observation tending to prove the main arguments in support of our position. Take, for instance, the very common incident of a large plant growth occurring right where there had been the previous winter a large drift of snow

lodged behind a windbreak in the field. The average farmer will readily explain it all by a statement that where the snow piled up on the ground it gave a certain protection to the grain, and that it acted like a blanket to preserve the grain from harm, thus assuring a better stand of the grain. But this explanation fails to explain. It does not get at the real truth. But investigation will show that the snow melted gradually in the spring, and by this slow melting process the water was able to percolate into the soil so that the moisture reached a great depth, and that this moisture was stored deep in the soil as in a reservoir, that later in the season, when the hot days came and evaporation was rapid from the surface, this stored moisture was supplied to the roots of the plants so that they kept on growing at a time when other plants in the field were checked in growth by the drouth. The soil conditions were different beneath the snow drifts. There was an abundance of moisture and it was deep in the soil. By capillary movement of the water at the right time, and having an inexhaustible supply of water at the source, the plants were supplied with what they needed, and growth was perfect, regardless of the climatic conditions which prevailed.

The incident is a valuable lesson in the storage and conservation of moisture in the soil, and the matter of the production of the proper physical condition in the soil to secure best results.

In the pages of this Manual it will be shown that the results which followed this accidental development of proper soil conditions may be duplicated on whole fields and that what was done by the chance piling up of the snow behind a fence or hedgerow has shown us what can be done in a larger way by cultivation in the right way

and at the right time. It will be shown that it is absolutely necessary, in regions where the rainfall is scant, that there shall be this storage of the water in the soil and conservation of the water so that there is no waste. The greater amount of water that can be stored in such a way that it will be used when needed, not only storage before the crops are planted but storage during the grow-

MONTANA WHEAT
Field forty-five miles southeast of Great Falls. Wheat grown Without Irrigation.

ing season, and the greater success had in so cultivating the ground as to save all this moisture for the use of the plant while growing, the better will be the results.

But aside from mere storage of the water there must be ever kept in mind this fact that both the cultivation

and the storage of the water are for the purpose of producing a proper physical condition of the soil. The soil must be in such condition that there will be the greatest development of roots. There must be development of roots and these roots must be able to take from the soil the elements of plant growth. There must be available fertility. The time comes nearly every season, in almost every climate, when there is severe drouth for a few days; and unless the roots are properly developed in good soil, disaster comes to the growing plants. It is not uncommon to find that the apparently fine growth of weeks is withered by a day or two of extremely dry and hot weather. Such could not be the case if the plant was prepared for such an emergency. The essential thing is to have the moisture available, to have the soil condition such as to develop good roots, and then drouths can be defied.

If the reader is interested in irrigation, then let it be borne in mind that the principles which are here applied are applicable as well to irrigated land. We have no doubt that much that is here written will be found especially useful to irrigation farmers—the moisture and its relation to soil fertility, the movement of moisture in the soil, the part played by air and other elements in the soil, and the general principles regarding fertility.

This book is offered to the intelligent and progressive farmers of the great west. And this term "the great west" has come to have a new meaning to very many in recent years. It is indeed the land of great possibilities. We have never more than half appreciated it in the past. It is a region which, under application of true scientific principles in the cultivation of the soil, is destined to be covered with countless homes of happy American families, with cities and towns prosperous and growing. May

God speed the day when the people will realize that these vast plains were not intended to be mere grazing lands for the few cattle companies, but that they will give support to many small herds and flocks cared for by many men, and that all the grass and cereals of the best agricultural regions of the earth will be grown here in abundance.

Ours is an age of progress in many lines. We are witnessing almost miracles in industrial and commercial life. Those of us who are devoted to the noblest calling of all should not be behind our neighbors in taking up with all that is good among the new things of the century.

CHAPTER II.

HOW TO USE THE MANUAL.

Complete mastery of the principles governing scientific soil culture is essential to success in practical field work.

These are the steps likely to be followed by one who will achieve highest success: Honest inquiry into the merits of the system, study of the question with mind divested of all prejudice, courage to apply the principles regardless of the influence of wrong outside teaching or influences, study over and over again of all that is here laid down in regard to handling the soil, intelligent application to conditions as they may be found affected by local influences.

One who takes up this Manual deeply or even slightly prejudiced against all things new and disposed to scoff at or criticise all teaching that does not have the recommendation of age, will make no headway. Honest doubts will not stand in the way, if the mind is free to accept the truth no matter who reveals it. But at a time when the most eminent students of agriculture throughout the world are admitting that their views are undergoing rapid changes, and when there is everywhere a passion for new things, new plants, new machinery, new methods —no man should be found disputing the conclusions of practical experience.

Then there must be not only courage to go right out into the fields and do the things which must be done for

success, but a desire to see true principles fairly tried. Sometimes the farmer starts out bravely to adopt scientific soil culture, but then he comes up against something that appears to be contrary to the teachings of his father

BURLINGTON MODEL FARM.

Crop of Wheat at Holdrege, Neb. in 1906, yielding 51½ bu. per acre testing 64 lbs.

or grandfather or a neighbor, and he resolves upon such a variation that he undoes all he has accomplished.

But the danger to the novice lies chiefly in his failure to study the method enough. He must know it well. The principles of scientific soil culture must be grounded

deep within him. He must be saturated with the subject. It must become part of his being. and this can only be accomplished by going over the subject many times and mastering every detail, always guarding against a wrong understanding of a seemingly minor question.

The professional man prepares himself for his vocation by long study of the books in which are laid down the general principles of his profession or science. The lawyer cons the big books which contain nothing but common sense principles. The engineer or architect or draughtsman spends months in special study of very simple principles. So also in this science or profession.

The vital point is ability to understand the soil, its relation to air and water and their combined relation to plant life, and the processes of development of soil fertility, so that the farmer may comprehend fully the effect of various conditions, and the further fact that he himself can by cultivation control these elements; just what, when and how certain work should be done, what to guard against and what to encourage, and what results to reasonably expect.

The Manual must be studied well. It would be impossible to put into a whole library detailed instructions as to every phase of soil culture, adapted to every possible condition that might be encountered; but herein is laid down general principles from which the intelligent farmer can gain an understanding of what should be done. The Manual should be studied every month in the year, and while crops are growing it will pay to consult it every day.

To further assist the student in grasping all the many principles and details in scientific soil culture we have prepared a correspondence course of twelve lessons through

which a full understanding of all the points may be reached. There is no subject today the full knowledge of which means so much to the farmer as how to get the most out of his soil, for it is the key to his prosperity and happiness. Anyone interested in a thorough course can learn all particulars by addressing H. W. Campbell, at Lincoln, Nebr. There is so much to be made known on the subject that the farmer will not be able to get it all in one book or in one year.

CHAPTER III.

THE IDEAL FARMER.

One of the principles long followed in educational work is that the man who is well educated with a mind, under good discipline, is fitted for almost any sphere in life. In recent years this theory has received some rude shocks, and school men are finding out that the man who is really educated is one who **has some specialty** in which **he is better than others.** Therefore specialization has become the rule in schools and colleges and in all walks of life. The man who tries to be a good minister and a good lawyer at the same time is no more found. Neither do men try to be at once a blacksmith, a plumber and a shoemaker.

So it is in agriculture—men have found that it pays to learn all about the subject. Just because one is schooled in many books or has been successful in trade or a profession is not sufficient to qualify him for farming. He must know his subject and know it well. And at the basis of his science lies knowledge of the soil and its character and possibilities.

But the farmer must have a well trained mind. He must be keen of perception and broad-minded. He must be studious and keep abreast with the times. He should take farm magazines and read farm books. He ought also to have the daily papers at hand, and know what is going on in the world. All these things will give him power to reason. But above all else, he must have adaptability.

Agriculture is a science with new problems every year, and where conditions change the application of the principles must change also. The farmer must meet conditions as he finds them. With the true principles well grounded in him he must be ready to adapt himself to all conditions that may come up.

The problem of farming in what is known as the semi-arid region is quite different from that in the humid portions of the country. The old methods will not get results. The farmer who must readily adapt himself to this fact will be quickest to achieve success. Farming, for instance, in the lower portions of the Ohio and Mississippi valleys is comparatively easy. The farmer has water to waste, and he does let it go to waste. Of course he would do better farming if he did not waste his water, or rather if he had it under control perfectly, as he might have, but in fact, he can farm very well and be indifferent to the waste of water. Not so everywhere.

As a matter of fact the men who have been making a success of farm operations in the region between the humid belt and the western mountains are men capable of working out hard problems. They have actually been engaged in solving these hard problems for many years. The early land seekers made the mistake of trying to farm as they did in the states where they formerly lived. The later farmers profited by their experience. As a result ideal homes are springing up all over the western states.

All this may be dismissed as intelligence in farming; but it is true that there has been entirely too much farming done without this intelligence.

The ideal farmer is first of all a student, then an investigator, and finally a specialist; ever alert for new things and new ideas, open-minded and free from conceit;

a man familiar with what is going on around him, and yet intensely devoted to his own work.

In order that we may realize our fondest hopes as to the future of our country our farmers must be men who are capable of developing their industry to its fullest extent.

FEASTING TIME.
Watermelons Raised in Lincoln County, Col., by the Campbell System.

This ability must have a scientific basis. It need not be wrapped up in terms so strange that the farm lad may turn away in despair. Science requires only words that we can all understand. But I am sure that if the young men and women of today would throw away that old delusive idea that soils produce just in proportion to the sunshine and rainfall and that these are matters of chance,

and that the physical condition of the soil has little or nothing to do with the crops, there would be a better feeling as to the safeness and sureness of agriculture. Then the farmer should try to comprehend how God has provided the necessary elements for the germination of the seed and growth of the plant; but it has been left to man to discover what is necessary under all conditions to develop the magnificent crop of cereals or to cause the gardens to glow with the beauty of finest flowers. Man must prepare the way. He must combine the different elements and give direction to the forces of nature. It is a study worthy of the greatest minds of the world. It is a science which the ideal farmer must know.

There has been a good deal of tendency in recent years to follow the cry of back to the farms; but if the nature of the science were better understood and men were more familiar with what has been accomplished and what lies just ahead, I feel sure that public sentiment would change radically and that rural life would be far more popular than it is now.

Scientific methods under the guiding hands of the ideal farmers are rapidly eliminating the drudgery of farm life. Our teachers in schools and in literature are not so much teaching a way to avoid work as they are showing how more can be accomplished with a given amount of work. It is being shown how larger crops and surer crops are to be garnered. The men and women of the farm are being awakened to the fact that they are not mere toilers, but important factors in the affairs of the world. It is open to them to make real progress, for if they do all that they should they will discover methods of improvement, and by their investigations show the way to better methods for the production of crops.

More and more it is becoming recognized everywhere that farming is the one business that all others depend upon. No other business or profession is so important from a material standpoint. It supplies that from which all other development proceeds. But it is not what it once was. It is not an incidental calling. It is the business of millions of the very best of the people of the earth. These people have a broader outlook and are facing greater possibilities than ever before.

The tendency is now as it must ever be to the small farm as against the "bonanza farm," which has so much characterized the newer portions of the United States, The abolition of the bonanza farm, which is inevitable. will change the whole feeling toward farm life. The small farmer is the one who gets the most out of his work. He is the one who develops. He will follow the more intensive system of farming. He will do the most to develop his state and country.

And the small farmer is the one who makes his farm his home. He seeks comfort for himself and his children. He does not build a shed to shelter him during the crop season with his family miles away. He becomes a permanent fixture in his country. He builds good houses and barns, he gets the best cattle and horses and hogs, he has a garden of flowers and he plants trees. He wants the school house to be located not far away and he willingly taxes himself for support of the school. He contributes to the erection of a church in the village and he is careful that the rural route and the co-operative telephone do not pass him by.

The ideal farmer makes the ideal farm, and in turn there is compensation quite enough.

CHAPTER IV.

BASIS OF PROSPERITY.

Prosperity is a sort of endless chain. The dollar goes round on a debt-paying tour and everybody is happy. If the dollar stops somewhere along the line then everybody is gloomy.

If you set out to explain this and devise a chain for the dollar to follow in its rounds, you will invariably include the farmer somewhere in the circle. If you begin with the grocer then you will go on to the miller or the baker or the packer, and soon back to the farmer. You may begin with the lawyer and his fee in court, or the minister and the contribution box, or start down in the "pit" of the stock exchange where gambling goes on daily—but you will always follow back to the farmer if you go long enough.

The farmer himself is a consumer as well as a producer. The farmer is always buying something. He seldom hoards up the money he gets from his sales of grain or steers. The farmer is a consumer of manufactured goods, and when he has money in abundance he buys freely of the things which are made in factories. Finally the circle is completed, and the money comes back to him in purchase of more of the farm products.

If the farmer is prosperous then he is a buyer. But the farmer more than any other person on earth can get along fairly well for a time without any general buying if he is compelled to do so. He can and does economize

more than others when his bank account is low. And so when conditions are such that men begin to retrench in expenses the farmer is one of the first to do so, and soon the chain of prosperity is broken at avital spot. In like

CORN IN COLORADO.

Grown Ninety Miles East of Denver in 1906 by the Campbell Method.

manner it is certain that as long as the farmer is spending money freely then others will have something with which to buy things or to pay debts. The farmer's good times means good times for everybody.

Now the farmer is prosperous just as he has abundance

of crops of all kinds. It matters not that the gold production is becoming greater each year and prices are advancing steadily, unless we are to have good results from agricultural operations. Nobody cares about high prices unless there is something to sell. We have here in the United States an era of great prosperity simply because there has been for a number of years a steady increase in farm production, not a spurt one year and a failure the next, but continuing good crops over large areas of the country.

This is the true basis of prosperity. It is therefore of real interest to men in every walk of life to do all that is in their power to have continuance of the success of the farmers. Therefore the business or professional man helps himself indirectly when he in any manner aids or prompts the farmer to gain a better knowledge of his soils and scientific soil culture.

It used to be said, and with much truth, that the great safety valve for the whole economic system of the United States was the free homes of the West. Whenever industrial conditions became unsatisfactory in the manufacturing centers the surplus labor was shunted off to the free or cheap land of the west. Now, that this practically free land is no longer obtainable, the same effect comes through increase in the producing power of the farms already occupied. The farmer cannot cure his dissatisfaction by turning quickly to unoccupied land; he can increase his product and output by applying better methods to his farming operations.

Few people realize how this process of getting more out of the soil by means of scientific farming has been developed in recent years, especially in the middle and

western states; much less do they realize what an important factor this has been in furthering the immense expansion of business in our history.

It is no small matter to effect a change so that on a million acres of farm land the yield of grain is doubled in quantity. The farmer who is contented with 15 bushels of wheat per acre when he gets a crop, and counts on missing a few seasons because, as he thinks, the "luck of the weather" was against him, immediately becomes a man of much more importance to himself and the community when he discovers that he can get 30 to 40 bushels of wheat every year on the same land by application of a little science under modern methods. This is just what has been taking place in recent years, especially in that section of our country once set down as of little value for farming, but now recognized as our choicest region.

Because of this development upon these western farms, because of the application of scientific farming, because of the steady increase in the output of the farms, there has come to our country unexampled prosperity in every line. The towns are growing, the cities are expanding, railroad lines are being built, the banks are busy, the merchants are doing well, the factories are running over-time, the workingmen are getting better wages, everybody is better and happier. The problem of maintaining this prosperity which so much delights us all is, therefore, not one related to the kind of currency we have, the paying of bounties to ship owners, or to the treatment of the tariff; but that of maintaining a steady average of profitable crop production.

The student of social economics must fail entirely who underestimates the importance of scientific soil culture in the creation and maintenance of our prosperity.

CHAPTER V.

SMALL FARMS; BETTER FARMING.

The struggle to get that which will sustain life in quantities sufficient to always satisfy all the people has been going on since the garden of Eden ceased to yield of its fruit an over-supply. It seems that there will never be enough of the good things of life. There can never be permanently any too great production of the things which come from the soil to supply the needs of man. The cry is ever for more.

The people of the United States nave been favored for the century and a quarter of national existence by the fact of their always having near at hand a vast supply of cheap unoccupied land, so that when production fell below requirements some men could move out upon the unused land and rapidly increase production by expansion of the agricultural area. The statisticians of the states have done much boasting of how the production of their states has increased; but this increase has generally been because of the enlarged area under cultivation.

But the cheap land is about all taken. Attention is turned properly to the problem of how to get more out of the land already under cultivation. Here is a great corn state and a group of men conceive the idea that the average yield per acre of corn can be increased from 30 to 40 bushels or perhaps more. Great idea, and the people are delighted with the missionary work thus done. Another learns of a new variety of wheat more productive than any other and he is hailed as a great benefactor.

It is the same everywhere. The acres which lie in the so-called semi-arid belt have been utilized for grazing and they are yet our cheapest land. With the westward tide turned back from the coast and mountains, it has

CAMPBELL SYSTEM VEGETABLES.

Raised without Irrigation by Mr. Rice, ninety miles east of Denver, on Kansas Pacific, first season's crop.

become necessary that something be done to make these cheap acres yield more. And happily that something is being done. The intelligent tilling of the soil on the dry prairies is enabling these farmers to double their crops.

Instead of 7 to 10 bushels of wheat to the acre they are getting 30 to 40, and getting it every year. Corn and hay yield in corresponding amounts.

The result is exactly the same as that of opening up new land and increasing the acreage under cultivation. It is all that is left for the American farmer. He must farm better and get larger crops or admit that he has reached the limit of his productive capacity.

The profit of the average western farm is not half what it should be or could be if the farmer would utilize all present available knowledge. Our farming methods compare unfavorably with those of other countries. Compared with the amount of land under cultivation, we do not use a sufficient number of teams, nor employ enough labor, nor have the necessary equipment. The estimated average value per acre of machinery, teams, buildings and appliances in various countries is as follows:

In the United States	$ 9.00
In England	40.00
In Germany	from $50 to 100.00

The total is governed to some extent by the special farming followed.

The returns per acre from land in these three countries show even a wider difference. The United States has soil equally good and much of it even better than in the other countries named, yet the wheat crop averages a little over 14 bushels per acre for the whole country, while England averages 32 bushels and Germany 33½ bushels per acre.

The difference is largely due to the more scientific methods of farming in the old world.

The western farmer should look carefully into this

methods of farming, and especially make a study of soil culture, and determine for himself by intelligent reasoning, if he can not easily double his crop yield.

In the past few years prosperity has abounded. There is no question as to the close relationship between general prosperity and the steady production of the farms. When there is an abundance of farm produce going into the markets of the world all business thrives. That in the United States this constant prosperity covering a period of years has been due largely to the fact that the farmers have been successful in their efforts to greatly increase the per acre yield of their land is also beyond any question.

Every farmer should consider what it means to him individually to double his crops. He should also consider how important it is to make sure of good crops no matter what the conditions may be. This is what scientific soil culture does.

But we can never have much better farming until farmers content themselves with fewer acres for each one. There has been all too much spreading out so that one man tills, or directs the tillage, of many thousands of acres. Land greed has been the curse of farming. The farmer can no more do his best while trying to cultivate a thousand acres than by confining himself to a two-acre lot. He must have enough, but not too much.

Better farming means better farms, more comfortable farm homes, happier farm families, better citizenship, more nearly the ideal simple life.

CHAPTER VI.

A LOOK INTO THE FUTURE.

Spread before you a map of the United States, one of the old kind common to the geographies of thirty to fifty years ago. You may have to brush the dust from its faded surface if you find one such. Perhaps you can conjure it up in your mind. On such a map you will recall that there were large regions marked "great forests;" then other areas indicated as "high plateaus;" and others where the dotted surface indicated a desert just like that in northern Africa. Then the portions which the map makers regarded as strictly good were marked with innumerable rivers and lakes.

Compare this with a good railroad map of today which can be gotten from any first class agent. Note how the forest regions bave disappeared, and how seldom is there anything to indicate a high plateau. The mountain regions seem to have shrunk. And, behold! the fabled deserts have disappeared entirely.

But the transcontinental lines of railway have long stretches with few stations, indicating that in some portions of the country the population is small. All this is being gradually changed, yet the area of small population is still very large.

The semi-arid region of the United States lies west of the Missouri river, presenting first an irregular strip extending from the Canada line to Texas, through portions of the Dakotas, Montana, Wyoming, Nebraska,

Colorado, Oklahoma and New Mexico; then having sections surrounding the Rocky mountains and the Coast ranges, including large areas of Idaho, Washington, Oregon, Utah, Arizona and California. Here is almost a third of the United States where the rainfall is from 10 to 20 inches annually, where in many places farming by the old methods has proved a failure. This is the semi-arid region about which so much has been said. It is the dream of the irrigationist to "reclaim" large portions of this country. It has been the hope of the herdsman that much of it would ever remain public land that he might continue his grazing of large herds.

It is a matter of common knowledge that the soil of this region is of a texture admirably adapted to the best farming. The fact of the small precipitation has been the sole reason for the failure to develop this region. For many years it was believed that this was in fact a desert region. The gold seekers who followed the trails across the plains sent back word that the climate was such that this must ever be a worthless land. But as the years wore on, here and there a farmer tried to do more than herd his cattle and sheep on the short grass. A few successes were recorded amid many failures. But the slow plodding farmer has a way of winning success despite all theories, and today, all through this semi-arid region are to be found scattered farms where men have accomplished a great deal for themselves. The soil is, in fact, fine and rich, of loose texture, and generally free from objectionable traits.

It has been abundantly demonstrated that if farming operations are carried on in this region under scientific soil culture, if care is taken to conserve the moisture and not to waste it, if the soil is so treated that its fertility

will be made available, if there is plowing and packing and seeding and cultivation suited to the conditions as they exist in this vast region—then crops are large and sure, and farming becomes akin to an exact science.

And this can be done—is being done—will be done by millions where it is done by only a few today.

A few years hence and the so-called "plains" or "Great American desert" of the map makers will be dotted with

MONTANA WHEAT.
Wheat Crop of Thirty Bushels, Fifteen Miles South of Great Falls, Montana, Grown without Irrigatiou.

splendid farm houses and great red barns. There will be rows of trees for wind-breaks and shade. There will be orchards and gardens. The great fields will be tilled by the very best of modern machinery. Steam and electricity will largely take the place of horse power in the heav-

iest work, for this is possible here much more than in the cramped fields of the older states. Plowing and seeding and harvesting will all be done much more quickly and better than ever before. There are few obstacles to good work. There are no boulders to break the plowshare and no stumps to bend the sickle. It is a country admirably adapted to the ideal farming. And the men who go out to conquer this desert land and to compel success under adverse conditions are just the men to build up ideal homes.

It is in this vast region that railroad building is going on now more rapidly than any place else in the world. Nothing could be more significant. Men who invest their millions in railroad enterprises do not do so without consideration of what it means. A few years ago the railroad managers declared that if they could do so, they would pull up some of the tracks they had laid in this country; and today these same tracks mark the pathway of immense commerce. Because there were failures due to misdirected efforts on the part of the farmers is not proof that the country is useless. On the contrary it has been demonstrated, and this is better known by the railroad builders than by any others, that the semi-arid region is destined to be in a few years the richest portion of the United States.

Looking far into the future one may see this region dotted with fine farms, with countless herds of blooded animals grazing, with school houses in every township, with branch lines of railroads, with electric interurban trolly lines running in a thousand directions, with telephone systems innumerable, with rural mail routes reach-

ing to every door. It is coming just as sure as the coming of another century. The key has been found and the door to the riches has been unlocked.

How many millions will be supported upon this region? Nobody knows. But the day will come when those who tell of the hesitancy of their forefathers about trying to subdue this region will have to modify the truth if they are to be believed.

CHAPTER VII.

THE DISK HARROW.

There is no tool the farmer can own that can be used in as many ways and under as many different conditions, and turn him as much profit if judiciously operated, as the Disk Harrow. It can be used to great advantage when the plow could not be used.

It is not, however, a tool that can take the place of the plow and secure anything like fair returns, except in exceedingly favorable seasons when rainfall is ideal and opportune.

Thousands of acres of wheat have been put in with a disk drill, or by disking the ground and then drilling, much of which was never cut, and a still larger percent never paid the expense of growing.

Since spending so much time in scientific research of the soils and the implements with which to till the soils, we have become very much interested in the disk harrow and its great scope of usefulness.

The great value of the disk harrow lies in its adaptability to the protection of moisture, the preparation of the surface soil for the encouragement of rapid percolation of the rain water, and in thoroughly pulverizing a somewhat cloddy plowed field and getting an improved physical or mechanical condition of the soil. It has been used on thousands of acres instead of plowing, when it should have been used to precede the plow. We have quoted, under the heads of "Evaporation" and "Culti-

vation," instances where the early use of the disk for the sole purpose of preventing evaporation and preparing the surface to receive and utilize further rains, has resulted in giving the farmer increased yields of corn as high as twenty bushels to the acre. Think of twenty bushels of corn per acre for only forty cents of extra expense. In the handling of fields for summer culture there is no tool that can take the place of the disk harrow, cost of labor and value of work considered; and while it is not a tool that can be continuously used, we do not see how a man can successfully handle an orchard without it. The disk harrow may be used to prepare a field for a crop, and in connection with the plow, its work is most valuable. The complete pulverizing and thorough separating of the particles one from another in its rotating action, when proper diameter of disk is used, is perfect.

WHEN TO USE THE DISK.

We most urgently advise the use of the disk early in the spring on all stubble ground or old fields intended for spring crops. The value of this early work with the disk is inestimable, and the more arid the condition, the greater the value of its early use. No time should be lost after the soil has become sufficiently thawed and dry so that it will not stick to the disk. For best results double disk the ground by lapping one-half, the object being to thoroughly pulverize and loosen the surface for a two-fold purpose. To loosen and form a soil mulch to prevent the loss of moisture by evaporation as well as to break the hard crusted surface to promote a more rapid and complete percolation or soaking into the soil below of the early spring rains.

In addition to the subject of conserving and more effectually storing the moisture, is another question not

commonly considered, but of equal importance—that of the more ready admission of the air which is in two ways very advantageous, that of more quickly warming the soil and promoting a more ready chemical action necessary to the development of fertility.

THE DISK AFTER HARVEST.

In still another season of the year we find the disk of equal value, that is immediately after the small grain

Following Harvester with the Disk, a very profitable part of the Campbell system.

or any other crop is removed. It is advised whenever possible to follow behind the harvester and not allow the soil to be exposed a single day to the sun's rays after

the crop is gathered. It is very difficult to explain the value and importance of this work in sufficiently strong terms to permit the reader to grasp its full force and meaning. We will endeavor to give it in six reasons.

First: There is no time in the year when water held in the soil near the surface in sufficient quantities, will bring about so many valuable chemical changes as during the months of July and August. This is the season of the year when a vast amount of nitrates and bacteria may be developed, in other words, the fertility, the very elements that start your wheat off early in the fall with that dark green color, and has very much to do with its stooling, providing, however, your final work of fitting your seed bed is carried out as explained under "plowing" and "sub-packing."

The fact that the farmer loses sight of the real scientific or necessary physical condition of the soil in the plowing of his field for another crop, accounts for the failure of so many plowed fields to yield as much in dry seasons as fields that were simply put in with a disk drill and not plowed. How often have we heard farmers say: "I plowed my ground and fitted it thoroughly, and my neighbor hogged his wheat in with a disk and got a better crop than I did." In fact the man with the disk had produced a more scientific condition of the soil.

Second: If there is any moisture in the soil below, by preparing this fine mulch of a liberal thickness this moisture will accumulate in the firm soil just beneath. If no more rains come, your ground is in perfect condition to plow because of the moisture you have retained by the early disking.

Third: If you do not wish to plow in the fall this moisture can be carried over until the next spring, when

in case of a dry spring your soil, if properly handled, as I will outline later, can be planted, and the seed will immediately germinate and grow, while your neighbor is worrying about a dry country and may harvest nothing.

Fourth: Sometimes you may have teams and time to do some fall plowing for spring crops. If your soil is dry **it is folly to plow,** but if you have held the moisture in the soil, it is wise to fall-plow, providing you follow the plow with the sub-surface packer, firming the lower portion of the furrow slice while the soil is still moist, holding the moisture below instead of allowing the furrow to dry out, as it will, if left loose by the plow.

DO NOT GAMBLE.

Some say that with early plowing the rains will pack it, and you don't need the Sub-Surface Packer. If you want to gamble the price of a good crop that it will rain enough in the fall to do the necessary packing, then all right. However, let us consider one fact. How would you have come out in the fall of 1903 in western Kansas and Nebraska, the Panhandle of Texas, and all eastern Colorado, with practically no rain for eight months, from late August to early May, 1904? Just as a great many did come out. Better follow business principles and be sure. Gambling wins sometimes, but you can never bank on it.

Fifth: In case you wish to sow fall wheat this early disking may mean ten to thirty bushels more per acre. By holding the moisture as shown above, it will be seen that any subsequent rain will percolate more quickly and deeper. If the rain be a heavy one, sufficient to dissolve and pack the loosened surface, the harrow should be thoroughly used as soon as the soil is dry enough not to stick, and by all means wait no longer. When you are ready to plow for fall wheat your soil is moist. By following the

plow with the packer, and the packer with the harrow, you will have a fine, firm, moist seed bed and your wheat will come up, stool and grow rapidly, and you need have no fears of winter killing if the seed bed is in proper condition.

Sixth: In our last is found the most important fact of all, namely, that of having your ground in condition to carry your crop through any spring drouth that has ever yet occurred, with a sure good stand of wheat, and an early rapid growth.

SIZE OF THE DISK TO USE.

When disk harrows first came in use the common size was fourteen inches in diameter, and this size we still prefer, but the demand seems to be for larger disks, the farmers conceiving the idea that they draw lighter. While this is true, the pulverizing effect of the sixteen-inch is not so good as the fourteen, the eighteen-inch even less, and a twenty-inch we would not have on a farm. Just a moment's thought on this point, and you will readily see the reason

The larger the disk the slower it revolves, consequently the pulverizing effect is decreased as the size of the disk is increased. I have noticed twenty-inch disks rolling along when the ground was somewhat dry, and simply slice the soil, raising it up a little and letting it fall back in large clods in exactly the same position it was before the disk passed over. The process simply made little crevices and actually increased the evaporation of moisture instead of decreasing it. A fourteen-inch disk moving along at the same rate of speed would revolve faster, therefore, pulverize and completely reverse the soil. Don't buy a disk too large in diameter.

Always double disk by lapping one-half. This leaves the surface level if you drive so the outside disk will just fill the furrow left by the center of the disk just preceding. Keep the disk sharp. It pays Buy as broad a disk as you have horses to draw. Time is money. Always precede your plowing by thoroughly disking. It helps materially in obtaining a fine, firm root bed. New and improved disk harrows are the next thing in order.

CHAPTER VIII.

PLOWING.

In outlining a general plan for the preparation of our fields for the best possible results in crop growing and grain yields, the plow takes first place as the all-important tool. The kind of plow used is not so vital as the how it is used, and what the condition of the soil is or should be when used.

Many have attempted to fix the time when the plowing should be done, whether early or late, fall or spring, in regard to which we would assert that there can be no fixed rule for time or depth of plowing. For the purpose of securing the best results the farmer must first take the precaution to prepare the field for plowing as outlined in the chapter headed "The Disk Harrow."

Many experiments have been conducted by the various agricultural colleges along the lines of determining a fixed rule for plowing, but the wide difference in results one year with another, when the attempts have been made to plow the same time of year or the same depth, shows conclusively that the simple fact of plowing three, four, six or eight inches deep each year, or plowing spring or fall, late or early, means but little, and the results shown cannot be taken as any guide whatever unless we consider the condition of the soil when the plowing is done, and what tillage has been done before plowing. If these questions are not considered, then the final result of the experimental crop is governed more by the soil condition

at the time of plowing, and the climatic conditions before and after plowing than by the absolute depth or time of plowing.

We desire to call attention to these facts on the start, that we may prepare the student to more fully grasp the real scientific principles

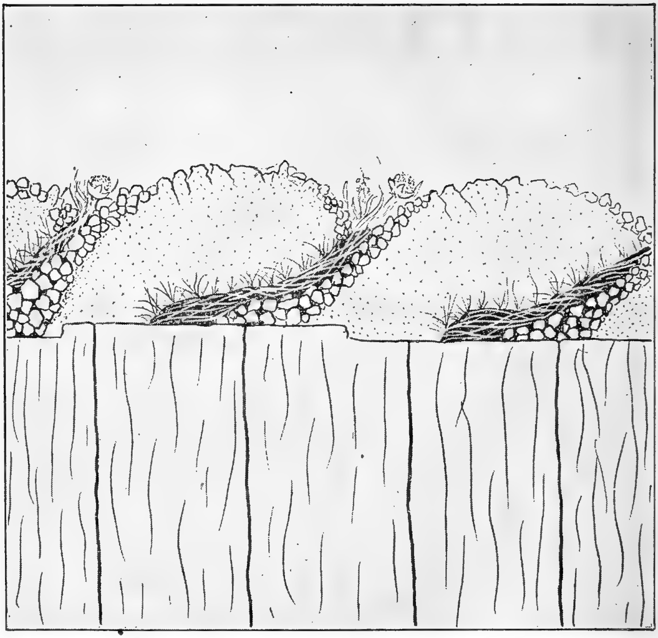
SPRING PLOWING OLD LAND.

The first and all-important work is the early double-disking as explained in the preceding chapter. It is nothing uncommon to see farmers double-disk by first going over the ground one way and then cross-disk it. This is not correct, for it results in a series of ridges and trenches, leaving the surface very uneven. The trenches left by the center of the disk each way over the field, exposes the solid soil in the bottom to the direct rays of the sun, causing an enormous evaporation resulting in a thick hard crust which breaks into coarse clods when plowed. The proper manner of double-disking is to lap half, which leaves the surface smooth and thoroughly pulverized. In the lapping of the half of the disk the last time over, the last disks revolve at right angles with the disks that precede. We cannot put too much stress upon this part of the proper preparation of the soils. Bearing in mind that the all-important element for the successful growth of our crops is water, we must lose no opportunity of conserving and storing the water from the earliest part of the spring to late in the fall.

WHEN TO PLOW.

Evaporation and percolation are more fully explained in chapters to follow. After thoroughly pulverizing the surface to stop the evaporation we can do our plowing a little later, regardless of the climatic conditions which may exist, and we shall find the soil in a moist condition.

It is very important that much care and attention be given to the condition of the ground at the time the plowing is done. Land should not be plowed when in bad physical condition, for good physical conditions are very necessary for an abundance of available plant food. This cannot be obtained in the seed and root bed unless this

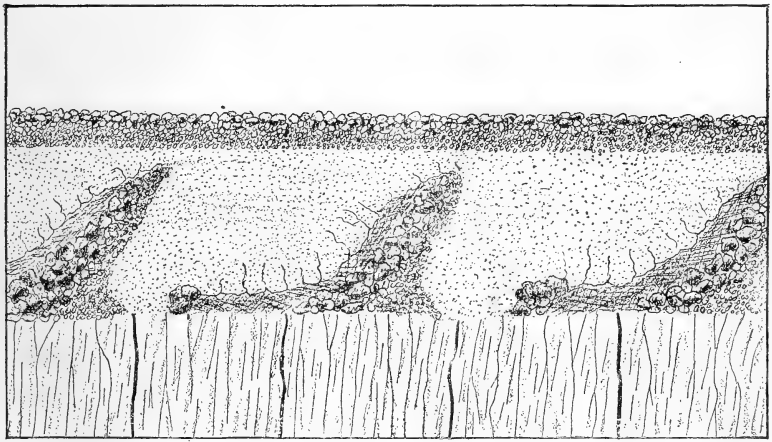


Cut No. 1. Showiug Soil as the Plow Leaves It.

point is given careful attention. Devote special study to what we say with reference to the physical condition of the soil. It is one of the most important subjects in connection with the chapter on the water holding capacity of the soil.

In cut No. 1, we illustrate the common condition of ordinary plowed fields. Observe the appearance underneath the portion of the furrow that has been thrown over by the mould board on the side of the next furrow. This illustration shows a field that had not been disked before plowing.

Here is the stubble, weeds and clods that have rolled



Cut No. 2. Surface of Soil Harrowed but without Sub-Packing.

from the next furrow, while right at the point where the furrow is tipped over the soil is firm from the bottom up. The usual manner of further preparing this ground is by the use of the harrow. This has a tendency to level, and, if shallow plowed, to work the ground down fairly well at the bottom of the plowing. In deep plowing, of six or more inches, the harrow has but little effect upon these cavities underneath. This is a very serious proposition, and it is the source of many bad conditions which

have a direct effect upon the final yield of the crops. First of all, it cuts off the seed or root bed from the sub-soil, preventing the movement of any moisture up into the root-bed. It also forms air spaces or cavities where a volume of air may exist, which aids in drying out the soil immediately adjacent. It also prevents the lateral roots and feeders from extending and permeating this portion of the soil, leaving a large per cent of our surface soil in a condition not at all beneficial to the growing crop.

In cut No. 3, we show the cross section of the same two furrows shown in cut No. 1. Here the cavities and loose condition of the soil at the bottom of the furrow have all been obliterated by the use of the sub-surface packer, which is illustrated in cut No. 5. These sharp wedge-faced wheels have both a downward and a lateral pressure against the soil in the spaces between them. The soil is moved by the packer in such a manner as to form a firm and evenly packed stratum at the lower portion of the furrow.

EFFECT OF THE DISKING.

A word about the disk. Had this land been double-disked before plowing, the stubble, weeds or manure shown in a strip at the bottom would have been scattered through the lower part of the furrow, the soil made finer and the packer would have made it more uniform and firmer, increasing its water-holding capacity. This would have promoted more general nitrification, facilitated greater and more uniform root growth and made it possible to have even doubled the yield of the crop, for it is not uncommon that a little more available fertility just at the proper time would have increased the yield fully two and possibly three times.

PHYSICAL CONDITION OF SOIL.

When our farmers grasp the real meaning of the little things just referred to, that is, that a certain physical or mechanical condition of the soil must exist where the roots and rootlets should grow, and that this condition is governed by the time and kind of tillage, and that only a slight variation from the ideal condition because of unscientific tillage or fitting may, and often does make, five, ten or twentv-five bushels per acre difference in the yield, then it is that we shall know by results what the possibilities of our great prairies are.

After the packer has been used, by then employing the ordinary smoothing harrow, or any late improved harrow, the surface is pulverized and made fine and the lower part of the upper portion, which is shown as loose and coarse in cut No. 1, is made firm, forming a perfect seed bed. The lower part made firm by the packer forms the main root bed, while cut No. 4 shows field complete.

MANY IDEAS AS TO PLOWING.

With this general explanation, let us return to the subject of plowing. With the varied experiences of the average farmer throughout the semi-arid west there has arisen a great variety of ideas with reference to depths of plowing, and whether it is advisable even to plow more than once in two or three years. Some have resorted to double-listing, each farmer believing he has conceived a very plausible reason why he should plow three or five inches or why he should not plow at all. I fully appreciate the honesty and good intentions of the farmer, but the reason there is such a great variety of opinion is because he does not grasp the importancc of having a certain physical condition of the soil, one that is favorable to holding the largest amount of moisture to the square inch; one that

is favorable to the most rapid movement of moisture by capillary attraction; one that is most favorable to the development of the greatest amount of available fertility, and one that is favorable to the most prolific growth and development of the lateral roots, with their thousands of little feeders. This condition cannot be secured at its best and the largest productive results obtained without thoroughly plowing, pulverizing and packing the soil each and every year.

All of the above mentioned conditions are gained by plowing at a sufficient depth to stir the soil which will later contain the major part of feeding roots.

In further discussing the question of what is the **proper physical condition of the soil** when plowing is done, we would call your attention to the furrow as it is turned over by the plow when the soil is simply moist—neither very wet nor very dry. How nicely each little particle of soil seems to separate, one from the other, when, if too dry, a cloddy condition is observed; and the same is true when the soil is too wet. We should try to secure the most uniform, fine condition of our soil for the four-fold purpose above referred to. By close observation and careful attention to these important points we may secure a crop result fully one hundred per cent greater than we could obtain if these items were disregarded.

PROPER DEPTH OF PLOWING

Let us first consider the simple question of deep, medium, or shallow plowing from its standpoint alone, without considering the condition of the soil at the time, or the kind of tools we are going to use after plowing.

This brings us to the position of the average plowman

up to a very recent date. All he considered in getting ready to plow, was to get his other work out of the way, then go at it and rip it up.

Many farmers and experimenters have endeavored under these rules to ascertain the most desirable depth of plowing for best results, and after trying one piece, say, three inches, another five, and another seven inches deep, for three or five years, they have found themselves all at sea. One year the deep plowing gave best results, possibly the next year it gave the poorest; while the medium or shallow came in ahead, and all because the farmer had no conception whatever of the true principles of developing or promoting available fertility. His plan of procedure was a gamble, and left him entirely at the mercy of kind Providence in the doling out of rain and sunshine. If the rains came at the proper time and in the proper quantity, interspersed with no long, dry periods, the game was his; but if the reverse was true, then his deep plowing that did so well the previous year, gave a light crop, or nothing at all.

Had this one question alone in Soil Culture been fully understood twenty years ago, the central west would have never felt the pangs of adversity during the panic of the early nineties, nor would hundreds of eastern widows, orphans, ministers, school teachers, and savings banks lost millions of dollars in western mortgages.

FALL PLOWING OLD LAND.

After discussing the pros and cons of spring plowing, it would seem that we had exhausted the subject. Not so, in the least. One of the most important questions we have not yet touched, and that is, what may be done to very materially increase the chances of a big crop of wheat following wheat?

The following of a harvester with a disk as shown in illustration elsewhere, is one of the little things that mean much. Especially is this true in the growing of winter wheat in the more arid sections. There are two very prominent reasons for this:

First, by repeated experiments we have found it very important in holding up the fertility of the soil to prevent its becoming dry either before the crop is planted, during its growth, or after it is harvested, in so far as it may be possible. Especially is this true in July and August, during which time the temperature usually runs high and the humidity low, causing an enormous evaporation and rapid drying out of the soil upon which the dead stubble of wheat or other small grain is left standing with the surface soil closely compacted by the rains or from irrigation. The stubble itself strongly attracts the sun's rays. By double-disking we are able to mix the stubble and coarser roots among the loosened soil, forming a most ideal mulch to prevent further evaporation, and if you have been careful to conserve all your moisture in previous years, you will soon find the firm soil beneath this mulch quite moist.

INCREASING THE FERTILITY.

This moisture, together with the nitrifying air that freely permeates your mulch, together with the heat, will develop more or less bacteria and nitrates, and really increases the available fertility in lieu of depleting it, as is true when the field is allowed to dry out under the more common methods.

Second, by the disking you prevent the loss of moisture, this peculiarly desirable condition causing this moisture to gather in the hard soil just beneath the mulch,

putting your field in ideal condition to plow, and by using reasonable caution to harrow or again disk in case of excessive heavy rains you can plow at any time.

CONSIDER SOIL CONDITIONS.

The proper depth of plowing, as we have previously attempted to show, must be governed very largely by the condition of the soil, the time of year that the plowing is done, the time it is to be seeded or planted, and the kind of tools you have for the after work.

Take the average prairie soil, especially if level with a sand loam formation: I advise plowing fully seven inches deep if to be seeded or planted soon after. But to do this and anticipate a fair crop, the soil must be moist and not wet. The surface must be thoroughly disked before plowing, and the sub-surface packer **must follow close to the plow.** The plowing done before noon should be packed before going to dinner. and that done in the afternoon packed before leaving the field at night, and then follow with the harrow to get the surface in good condition before the clods get too dry.

In case of early fall plowing, for spring crops and moist soil, if you have sufficient team, it will be found profitable to plow eight inches deep, following with a packer and harrow as above mentioned. If you have no sub-surface packer, beg, buy or borrow one. If you have no packer, I would not advise plowing over five inches deep, and use the common harrow with teeth slightly slanting and weighted, the object being to pulverize and firm the under portion of the furrow. But don't figure on getting the same results from the five inch plowing thus fitted. These observations are very important.

EVEN FURROW SLICES.

Much care and attention should be given to the furrow

slices that they may be even in width and depth, so that when you go over the ground with your packer or harrow there may be no soil spaces left loose and porous. The average farmer must realize the great importance of thoroughly fining and firming the entire plowed portion. In the ordinary conditions as found at the bottom of furrows in plowing left without any further work until it has all dried out, shown in cut No. 1, fully one-third of the soil contributes no nourishment whatever to the growth or production of the crop. By adding a little extra pains and labor that one-third of non-productive soil may be put in condition to do its full share in making a larger and better crop, while the remaining two-thirds will bring far better results. By closely following this rule you will greatly increase the certainty as well as the quantity and quality of your crops of small grain.

BREAKING NEW PRAIRIE LANDS.

There are two questions to consider in breaking new prairie, both of which are quite vital.

First, what can or should be done to promote the quickest and most thorough decomposition not only of the sod that is turned over, but of that portion of the soil just beneath the sod that we expect to turn on top in our next plowing.

Second, how to get all the rainwater possible to pass below the sod, and there conserve it.

When we went to Dakota in 1879, the idea was very prevalent that the sod as it was turned over should be allowed to kink up and lie loosely on the surface. This we soon found was a very erroneous idea for the semi-arid sections, a plan that might have originated in early Illinois home making.

With fourteen years' farming in Dakota, we became

very much prejudiced in favor of breaking only when the grass was growing the fastest. Other facts and conditions have developed to that degree that we have practically lost sight of this idea except in the more humid sections.

The marvelous and rapid change of the big pastures in the great semi-arid sections of this country into farming sections through Scientifie Soil Culture during 1905 and 1906 has brought forth thousands of inquiries as to how these prairies may be opened up and a crop grown the first year.

Having opened up two farms of this nature in the Panhandle of Texas, and observing many other fields during the above two years, coupled with our early experience with sod breaking in the Dakotas in 1879 to 1889, we find the best plan, if possible to do so, is to break the fall before.

FALL BREAKING.

We are assuming that we have what is commonly known as buffalo sod. For best results we would break as early in the fall as it may be consistent, and as to depth of breaking would be governed by the tools we had to operate with and kind of crop we desired to plant.

If for spring wheat or oats break about three and a half inches deep, using the walking rod breaker, and using the greatest possible care to turn it flat. Follow with a smooth roller if one can be had. In lieu of this, use the sub-surface packer, going twice over the field, then harrow to fill the crevices, and leave until spring.

As early as conditions will permit, double-disk, setting the disk levers as far over as possible, and not turn

up the sod from the bottom. Then harrow thoroughly with common smoothing harrow, teeth slanted back and weighted.

FOR POTATOES, VEGETABLES, ETC.

Follow same plan as above outlined, except break about three inches. after treating as above outlined, plow again with stirring or stubble plow about two inches deeper, following the plow with the sub-surface packer, then harrow.

In case fall breaking is impossible and spring breaking is imperative, follow practically the same plan of fitting for the different crops, but of necessity the breaking must be early. Bear in mind the soil must be fine, and at the bottom as firm as it may be possible to get it.

The disk plow may be used. It is only a question of getting the soil as fine and firm as possible for reasons frequently reiterated all through this volume. Very good Milo maize and Kaffir corn can be grown in the same manner for feed for teams.

When necessary to spring-break sod, we would not advise sowing oats in a section where the rainfall is less than 20 inches annually. It is by no means a sure crop on sod, no matter how it is fitted. It is not wise to risk any more on sod than necessities demand.

BREAKING SOD FOR FALL WHEAT.

There is very little prairie sod now unbroken except in the more arid sections, and we believe in turning it as quickly as conditions will permit, and so far as it may be possible, break tbe fall before you wish to crop, as it will pay. If at any time you have some leisure, turn over some sod as flat as you can. Roll it to make it lie firmly against the subsoil. The packer does very well if you have no roller. Keep the surface worked

after heavy rains. If you can't loosen it with any other tool, disk it. Watch, and so far as possible, harrow when the surface is just moist. This will prevent the loss of any moisture, holding it as far as it may be possible beneath the blanket, and in case of heavy rain harrow again. With this blanket properly provided during June and July the sod itself will not only be found to be well rotted but the top of the subsoil to a depth of one to three inches also. In August, or as soon as the soil beneath the blanket is rotted, it should be plowed again, this time with the stirring or stubble plow, cutting about two and a half inches deeper and following with the sub-surface packer, the same as outlined for ordinary stubble plowing. The harrowing should be very thorough.

If care has been taken to conserve the rain waters and the work well done, this ground may be planted to fall wheat or to spring crops the following spring, after which it should be treated the same as old ground, except to run the plow two inches deeper the next time.

There is no economy, but on the other hand, great waste, in trying to economize or minimize the amount of labor required to thoroughly prepare the soil for the sowing or planting of grain, for the work of thorough preparation is easily and quickly done, and when once done a successful harvest is assured.

CHAPTER IX.

SUB-SURFACE PACKING.

By sub-surface packing we mean the packing and firming of the soil at the bottom of the ordinary furrow by a mechanical process and the elimination of the open spaces between large lumps of the earth.

To those who have been drilled in the theory of subsoil plowing, and who have been taught that the chief thing is to open up the under soil as much as possible, or those who are not familiar with the great difference there is in soils in different sections of the country, the suggestion of the necessity for firming the sub-surface will come as a shock.

This sub-surface packing of the soil is something that even the professional students of the subject have found hard to understand. It is something against which some of them have protested, because they have failed to understand all that is involved. But it is a principle which is making its own way. As we will show elsewhere the interest in the subject is increasing at a great rate. Appliances for accomplishing this result are becoming more and more in demand. Practical farmers are learning that it is the thing.

Sub-surface packing is a purely mechanical process. Special tools are on the market for doing this work, but no matter what tool or implement may be used, the principle is just the same, and results will follow in proportion to the success which has been attained in doing this nec-

essary packing and at the right time. Elsewhere is described more in detail the sub-surface packer especially devised for doing this work, a machine which is winning its way because of demonstration that it has a mission to fulfill and is doing it.

Sub-surface packing of the soil is a process of following the plow immediately or otherwise with implements which crush down the loose soil of the under portion of the furrow slice, breaking up the large lumps, compacting the whole so that the particles of soil lie closer together and form a perfect connection between the unbroken earth beneath the surface and the loosened soil of the furrow. It is not compacting the surface layer as by a roller, for that merely invites waste of the land as dust. It has reference solely to that portion of the soil which lies near the bottom of the cultivated upper soil.

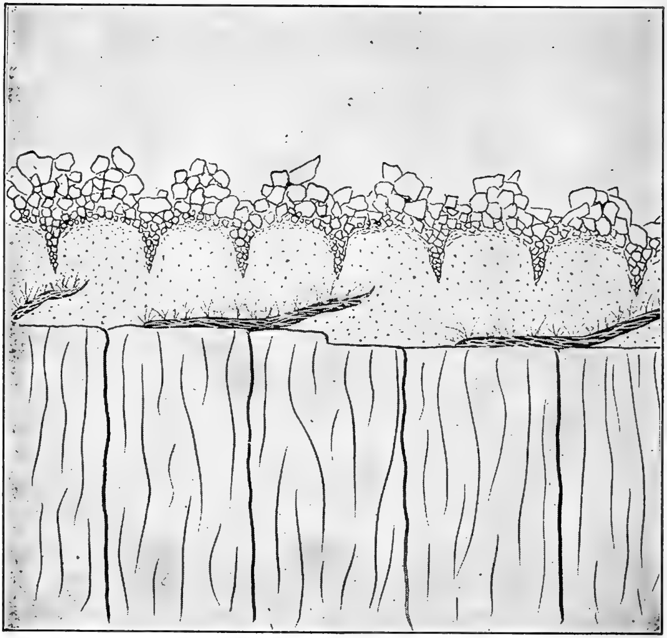
Nature has placed at the disposal of man all the necessary conditions and elements in the sand loam soils on the level prairies of the great semi-arid belt, together with the properties of air and water, aided by heat and light, to produce large crops every year, but has wisely left it to man to work out the manner and method of combining these elements; and it is now apparent that the combining or utilizing of these elements must be upon strictly scientific principles, or in plain English, there must be correct principles under these ideal conditions and every part of the work must be done precisely at the proper time and in a correct manner.

MISSION OF THE PACKER.

The Sub-Surface Packer has a vital mission to perform. Its main object is not that of aiding in storing the moisture in the soil, but that of controlling or equalizing the holding capacity of the soil for both air and water.

It is not the purpose of this tool to simply hold up the present normal yield, but to greatly increase the present average yield by from 50 to 250 per cent.

Experiments repeated over and over again in a variety of soils in the semi-arid belt, have proven conclusively



Cut No. 3. Showing Soil as the Packer Leaves It.

that in promoting or developing plant elements or fertility under such conditions that it may be available in large quantities, there must be in the soil just the proper quantity of both air and water. If there be too much water and too little air, or too little water and too much air, you cannot secure the best possible results.

In the latter lies the greatest danger, as a rule. If the soil is too coarse and loose, then the air exists in too large quantities, and the development of nitrates and bacteria is proportionately slow.

The condition has proven to be most ideal when the soil is thoroughly pulverized and closely compacted from the bottom of the furrow up to within two to three inches of the surface, while this surface layer of two or three inches, should be loose and composed of fine and medium lumps to allow of a free permeation of the air, and to prevent the moisture being depleted below the proper or normal quantity by surface evaporation.

Another important advantage is gained by the packing of this lower portion of the furrow slice, and that is, the increasing of the water holding capacity of the soil, enabling us to carry our plants over long dry periods without the least injury. There have been instances where this one advantage alone has made a difference of fifteen to twenty bushels per acre in the yield.

MOVEMENT OF WATER IN SOIL.

The movement of the water in the soil under varying conditions of the soil and the surface should be well understood. A discussion of the subject may not seem of interest to the average farmer, yet the well established facts in regard to this subject have great weight when carefully considered in connection with the preparation of the soil for crops. It is a subject altogether too broad and represents too much in dollars and cents to be held back from general use by mere prejudice or the skepticism that usually rises in the face of all new devices or methods.

Professor F. H. King, of the University of Wisconsin, undoubtedly one of the most learned men in soil physics

we have in the West, if not in the country, in 1895 published a book entitled "The Soil," which book should be in the hands of every farmer. In treating the question of the effect of rolling on soil moisture, he says:

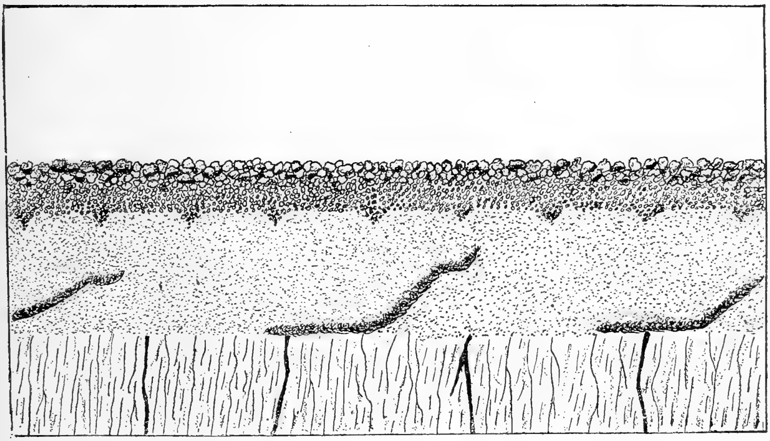
"When, however, the changes in the water contents of the surface four feet of soil which follow the use of a heavy roller are studied, it is found that we have here a case of the translocation of soil moisture, a case where by destroying the many large non-capillary pores in the surface soil, and bringing its grains more closely together, its water-lifting power is increased and to such an extent that often within twenty-four hours after rolling the upper one or two feet beneath the firm ground have come to contain more moisture than similar and immediately adjacent land does at the same level, while the lower two feet have become dryer. Water has been lifted from the lower into the upper soil.

"In the table below will be seen the difference in the water contents of the soils which have been rolled and the immediately adjacent ones not so treated. These results are averages derived from one hundred and forty-seven sets of samples, therefore not a conclusion of theroy, but one of fact, from continued repeated practical results:

	Per cent of water
"Surface 36 to 54 inches, unrolled, contained	19.73
Surface 36 to 54 inches, rolled, contained	18.72
Loss by rolling..................	1.01
Surface 24 to 36 inches, unrolled, contained	19.85
Surface 24 to 36 inches, rolled, contained	19.29
Loss by rolling..................	.56
Surface 2 to 18 inches, rolled, contained	16.85
Surface 2 to 18 inches, unrolled, contained	15.64
Gain by rolling..................	1.21"

ROLLING VS. SUB-SURFACE PACKING

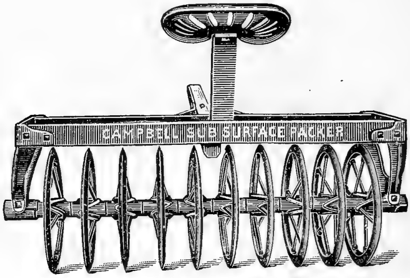
It is here seen that when samples of soil are taken at a depth exceeding two feet, the rolled ground as a whole is dryer than that not rolled, and that this difference is greater when the samples are taken at a depth of from three to four or more feet. The data presented also shows that the two to eighteen surface inches of loose ground recently firmed contains more water than that which has not been so treated. It is a matter we have



Cut No. 4. Showing Soil after Packing and Harrowing.

carefully studied, and in all our experimental work we have observed that the statements of Professor King have been verified fully; thus affording conclusive proof of the truth of all that we have said with reference to the sub-surface packing of the soil. When the extreme surface is packed the effect is to draw the moisture to the surface where it is lost by evaporation. By the sub-

packing, as shown in cut No. 4, we have that firm stratum at the point where the roots mainly grow, and with our loose mulch on the surface we prevent the loss of our moisture by evaporation.



Cut No. 5. Sub-surface Packer.

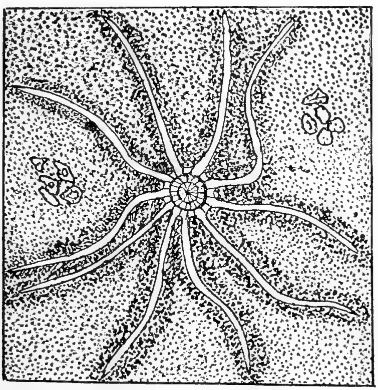
Results obtained by Professor King in these one hundred and forty-seven tests certainly prove very effectually the correctness of the conclusion of sub-packing. We secure a much deeper or thicker stratum of packed soil than can possibly be secured from a surface roller. This would of itself create a greater force of capillary lifting power. Then again, and don't lose sight of this fact, as the sub-packed soil lifts the moisture it is not lost by evaporation as is the moisture from the surface packed, but is held there beneath the loose surface or soil mulch. This fact causes an accumulation of moisture in the packed portion which further aids in the upward movement of the moisture from below. This translocation of water brought about by the sub-packing is of the highest importance when we reach the long dry periods so common in midsummer, a condition we rarely fail to get sometime each and every year. We have proven by practical tests, over and over again, that by this increased move-

ment of the moisture the plant is amply supplied, under which conditions the damage so common is not only prevented, but the plant has been able to make a rapid, healthy growth right through, while plants in ordinary manner have suffered and possibly been ruined because of shortage of moisture.

When we reach a point in the extreme heated portion of the last afternoon prior to a heavy rain, where our supply of moisture is beginning to shorten, the fact that we have by this sub-surface packing been able to lift the water stored below a little faster may be the means of doubling or trebling the yield.

Another point that has been but slightly touched upon is, that by this fine, firm substratum we are able to carry what might be quite properly termed a balanced quantity or ration of both air and water, thus bringing about that most ideal condition for the development of fertility.

DEVELOPMENT OF ROOTS.



Cut No. 6. Development of Roots in Firm Soil.

In cut No. 6, we represent the cross section of a lat-

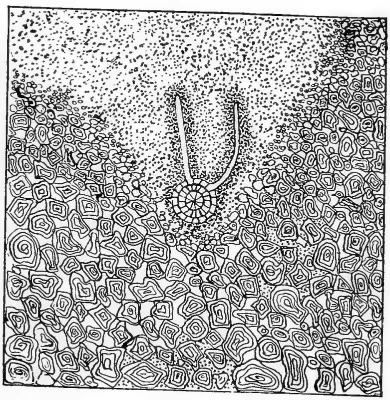
eral or branch root very largely magnified. The little branches running out from the center represent the little hair roots or feeders which are often so small that they are scarcely perceptible to the naked eye. These little feeders are neither more nor less than little tubes, or elongated cells. You will notice in the outer tier of cells each little feeder practically forms a part of the cell. The soil where this root is located is represented to be that ideal condition of fineness and firmness previously referred to, a condition that means so much to any plant, not only to sustain it in a healthy, growing condition, during critical drouthy conditions, but to promote a strong, healthy, rapid growth during the ideal climatic conditions.

In cut No. 7, we represent a coarser or less compacted soil. Here the lateral root is only able to send out two little feeders, This condition is very serious. We have examined roots many times and found them three, four, and five inches in length, with scarcely a hair root or feeder the entire distance. Then coming, possibly, to the packed soil beneath a horse-foot track, we would find a complete net-work of little feeders running in every direction. The one great reason for this greatly increased number of feeders in the packed soil is the fact of its ideal physical condition with its perfectly balanced ration of plant foods, just what the little rootlets go out after when they start from the newly germinated seed. Just keep your mind on this one fact, not only in the study of this Manual, but in your field work and observation.

MAKING THE SEED BED.

It is hardly possible to put too much stress upon the point of thoroughly pulverizing and packing the seed bed. Probably the strongest or most complete practical

illustration was brought out at the Pomeroy model farm, at Hill City, Kansas, in the growth and development of the wheat sown in the fall of 1901. This ground had been prepared with the greatest possible care, having been plowed seven inches deep, with the soil in a moist condition, kept so by the disking and harrowing of the surface. When plowed, the plow was followed closely with the subsurface packer, and the harrow following closely the subsurface packer. By endeavoring to do all the work when the soil was in proper condition, we had secured a very favorable physical condition. At the time of seeding, October 8th, 9th, and 10th, there was a fine loose mulch

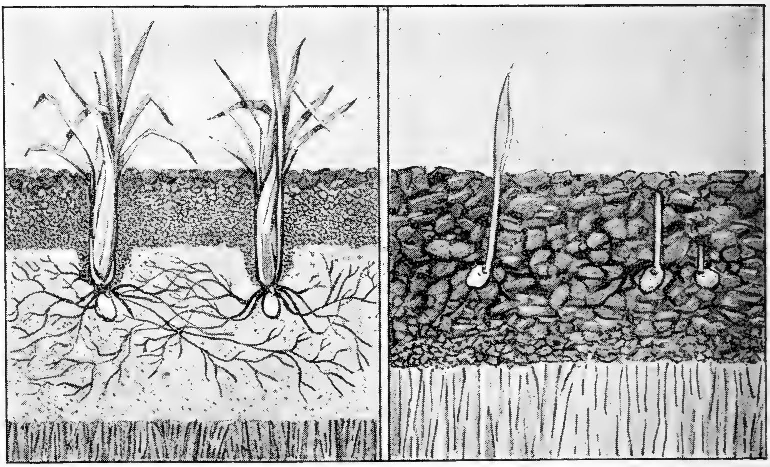


No. 7. Root Development in Loose Soil.

on the surface, two and one-half inches deep. The soil immediately beneath was very fine, firm and moist. The wheat was put in with a shoe drill, less than one-half bushel of seed to the acre, from one-half to one inch into this fine, moist soil, just beneath the mulch. Germi-

nation and development were rapid. The fourth day, as regular as the days came after seeding, the little green spears could be seen the entire length of the row. On the seventh day these leaves measured from three to four inches high. Thus, in seven days, the hard, dry seeds had become moistened, burst their shells, sent out laterally the little rootlets, and the little stalks had grown to a height of five or six inches from the seed. This is not all. On the sixteenth day of November, this wheat was taller and thicker than a field sown on the sixteenth day of September, with one and one-quarter bushels of seed on soil fitted without sub-packing.

In cut No. 8, we have two conditions of soil. On



Cut No. 8. Germination of Wheat Influenced by Firmness of Soil.

the right we have the more common plan. Here we find the grain of wheat in somewhat coarse and loose soil,

where the subsurface packer has not been used. It is in this kind of a seed bed that the wheat frequently remains all the fall without germinating; again it may sprout because of a shower only to wither and die from later dry windy weather, or perchance may absorb just enough to burst the shell and send the germ out slightly and a few feeble rootlets, then be completely ruined by the winter freezing because of a lack of moisture in the soil about the roots to draw the frost in thawing out. All this is because of an unbalanced ration, too much air and too little water.

IDEAL CONDITION OF SOIL.

On the left we have the ideal condition, a condition that can easily be attained at a nominal expense. By the use of the sub-surface packer when the soil is in proper condition as previously explained, we get that fine, even firm condition as shown, to a depth of seven inches; then with a good harrow we secure the fine, loose mulch about two inches deep; with the closed heel shoe drill we provided that V-shaped opening about one inch in the firm soil into which the grain drops. As it reaches the bottom it is surrounded, except over the top, with fine, firm moist soil. The fine dirt that very naturally fills this opening as the shoe moves along, puts our wheat where all conditions are as nearly perfect to utilize the greatest quantity of the greatest number of nature's provisions or resources for the rapid, healthy prolific growth of the plant.

The numerous small moist particles of soil that côme in contact with the wheat conveys the moisture quickly and in ample quantities. This, coupled with the air from above brings about the very remarkable germination and development shown at the extreme left of cut No. 8 in the short space of five days.

Study well this illustration and note the varied conditions. The single grain at the right in the left hand section is simply to show the surrounding condition as it is deposited, compared with those in the loose soil to the right. Do not simply look at the illustration, but study the relative condition and reasonable results that may be anticipated from each, and to aid you in this conclusion, consider well what has already been said with reference to the ideal physical or mechanical condition of the soil.

QUICK GERMINATION

This quick germination is always apparent in all our fields, and is invariably followed by early and prolific stooling, as shown in the chapter on wheat growing.

On the Kilpatrick Brothers' ranch in Chase county, Nebraska, where we had directed the preparing of some ground for fall wheat in 1903, the wheat was sown September 14th, two weeks after the last rain, the field being on a slope towards Champion, a town two and a half miles away. On the morning of the nineteenth, really but four days from seeding, the shape of the field was discernible from Champion by its green color. This statement may be emphasized from the fact that hundreds of acres of wheat were sown that fall, and not another one showed green that season. Because of over seven months without rain, beginning September 1st, the Kilpatrick wheat was all that was harvested in that county, making over thirty bushels to the acre, the rest being a total failure.

As a further evidence, let us refer to some of the more common conditions that have occurred and many times puzzled the farmer in years gone by.

In the spring of 1899 a large amount of winter wheat in the semi-arid belt was found to have been killed. We drove

over many fields that spring to investigate and study the cause as far as possible. One fact was invariably perceptible—where the soil was light and loose to a considerable depth, the wheat was entirely dead. In the more compact portions or spots in the fields, the condition of the wheat was found better. For instance, along the sides of the dead furrows almost all of the wheat was found to in a perfectly healthy condition, while on the back furrows it was usually all dead. Again, at the corners of the fields where lands were plowed around, and the horses in turning had tramped and packed the plowed ground, the wheat was found to be in good condition. The horse foot and wheel tracks invariably had a favorable effect. This is a condition and result that is corroborated by all investigators, that if there is plenty of moisture in the ground there is little or no danger of freezing or winter killing, while if the soil is loose and becomes too dry serious results follow. The same was fully shown in the quotation from the Illinois Agricultural college bulletin, portions of which we quote under the heading of "Raising Trees." These conditions bear out all observations, both with reference to the fact that packing the soil will increase the water contents of those portions, and the further fact as stated by the Illinois bulletin, that if there be plenty of moisture about the roots there is practically no injury from freezing.

VALUE OF HEALTHY ROOT SYSTEM.

One point which we have tried to impress upon our readers at different times, is the fact that plants cannot thrive and produce abundant yields without a perfectly healthy root system and a perfect root system is a physical impossibility in coarse, loose soils. Professor King has shown by practical experiments, and all observation

confirms his conclusions, that in soil that is packed the moisture moves upward from a depth of from one to four feet much more rapidly than in loose soil. It is therefore important to have this packing when a condition of extreme drouth is reached, as it may be the one thing that will save a crop.

Another very marked advantage of this sub-packing was found in our work at the Burlington model farm at Holdrege, Nebraska. In 1905 a piece of ground was plowed for corn; a strip was left unpacked but all was well harrowed and the corn planted the same day. Where the packing was done, the stand of corn was perfect, while the strip not packed had hardly a two-thirds stand, and the entire season's growth showed the advantage of pack ing. While the use of the sub-surface packer has been found valuable in Wisconsin and Illinois, the further west we get into the semi-arid country, the greater is its importance, while in the more arid portions of the semi-arid belt its use is practically indispensible.

It must be borne in mind that Professor King experimented in packing at the extreme surface, where nearly all the moisture that had moved to this point was lost by evaporation, and that had the packing been done just below the surface the contrast would have been much greater. Professor King's experiments were on the grounds of the Wisconsin college, where soil moisture is invariably found all through the soil down to sheet water. Had they been made in our semi-arid region, the contrast would have been greater. If we get our soil moistened here to a depth of four or five feet we have exceeded by some distance the usual conditions, and this depth of soil moisture would be sufficient to carry us any ordinary season in the successful growth of crops. Had Professor King's

experiments been made with a three inch layer of loose soil mulch above the packed portion, they would have shown a much greater increase of moisture at the point of two to eighteen inches.

EFFECT OF THE SUB-PACKING.

All these facts in connection with the movement of moisture in the soil, under different conditions of the soil, as indicated in the experiments noted and the teachings of the most eminent students of soil physics, give us the valuable lesson that the packing of the sub-soil, or what may be properly termed the root-bed, aids us in these important points; increasing the water holding capacity of the soil facilitates the movement of the water from below up to this point when it is needed.

The last but by no means least of the advantages derived from this sub-packing outside of what has been already mentioned, is that by the increased upward movement of moisture previously explained, we are able to keep up the supply of moisture about the roots to that degree that nitrification and the development of fertility continues though the weather be hot and parching, and the plant is growing rapidly, and yet through this ideal condition we are able to keep up the supply of plant elements in a soluble condition, thus giving to the plant that dark green, healthy, prolific growth without a set-back, which is, by the way, the secret of large yields.

Now let us take a last look at the field of grain trying to exist on a piece of land the root-bed of which is coarse and loose. The excessive heat has caused such a rapid evaporation from the leaf and the upward movement of moisture by capilliary attraction has been so slow that the moisture about the roots has become so depleted that nitrification ceases; all fertility has become unavailable,

the plant has taken on a pale, unhealthy look, and upon the time in season, and the duration of the period of drouth, depends the extent of injury to the crop.

This is so important that it may be stated again plainly, so that no reader may misunderstand. The process of packing the under portion of furrow or plowed ground creates five conditions to aid in carrying the growing crop over long dry periods, namely:

1. More water in the soil.
2. A stronger capillary movement of water.
3. More prolific growth of roots.
4. A more rapid development of nitrates and bacteria.
5. A larger per cent of available fertility or plant elements during drouthy periods or conditions.

CHAPTER X.

SUMMER CULTURE.

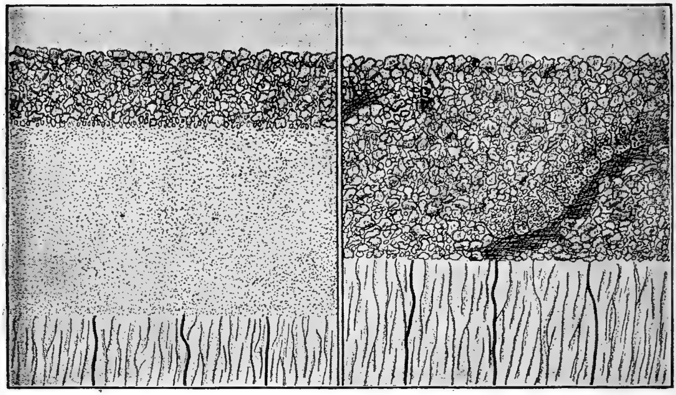
Under this caption we must of necessity, reiterate much that has been said in previous chapters, as it combines more ideas of soil tillage into new forms, combinations and uses than any other chapter. In fact, it was during our early experiments along this line that we discovered the marvelous possibilities of the soils under semi-arid conditions.

It was also while working out the most desirable methods in detail in Summer Culture that we first became fully convinced that the average yield of all cultivated fields in the more arid sections could be made to produce not only two and three times as much fodder and grain as had been heretofore produced in good years, but that good yields could be made certain in dry seasons, and it is since we have been proving the correctness of some of our conclusions along these lines, that Scientific Soil Culture has become recognized as the great factor in all agricultural development.

While many of the ideas and combination of ideas of Summer Culture are new, and their application and effect in the more humid sections are not yet fully proven; yet it is very apparent that the principles will prove of great value under all conditions and in all farming sections, but not to the same degree under humid conditions as under more arid conditions.

In discussing the details in general through this chapter we refer almost entirely to the soils and conditions ofthe more arid section.

In the development or promotion of many new devices that came into use simply as a matter of convenience



A B

Cut No. 9. Summer Culture vs. Summer Fallow. (a) Summer Culture as Applied by the Campbell Method. (b) Summer Fallow as Commonly Applied.

or pleasure or added comfort, great interest and enthusiasm is not uncommon. Again we see books of fiction put upon the market that soon find their way into nearly all homes, simply for amusement or entertainment.

Here comes a new science that means dollars to millions of people, not in a commercial way by which one makes a profit from another, but by bringing more wealth out of mother earth and filling increased granaries with but little extra expense beyond learning how—and once learning, you are always in position to command bigger incomes and get them.

Summer Culture has been confounded with Summer Fallow, the methods are so different that any conclusion that may have been derived from Summer Fallow experiments by our agricultural experts would not apply to Summer Culture; therefore, many of the objections held up or against Summer Fallow do not apply at all to Summer Culture, The most prominent is the rotation results.

EXPERIMENTS IN ROTATION.

For illustration, take the eight year rotation at the South Dakota Experiment Station under the direction of E. C. Chilcott up to 1906.

We would first call attention to some of the statements made in the bulletin with reference to the handling of the ground. Referring to summer fallow, they say all summer fallowed plats are plowed in July before any weeds have ripened their seeds, and are plowed again with the other plats in the fall. They are given no other cultivation during the season.

Referring to the corn plats they say corn is drilled in rows one way. It is given good clean cultivation with the drag, weeder and cultivator, each in its proper season. Referring to the preparation of the ground for the various plats, wheat, oats, and barley, they say. "The plats are plowed in the fall, usually in September, crosswise of the series. This necessarily involves plowing the corn ground and potato ground. We have found by other experiments that where the crop has been properly cultivated and kept clean there is on the average very little difference to be seen in the following crop whether the corn ground is plowed or whether it is drilled in without plowing. The ground is plowed at depths varying in different years from five to seven inches. As early as possible the in spring the ground is harrowed twice with an ordinary steel harrow."

From this kind of fitting as stated for each particular field the following results were obtained. From a seven years' rotation, wheat after corn, the average yield of wheat was 15.9 bushels. In the rotation of wheat with summer fallow, same number of years, the average yield of the wheat was 15.8. In these rotations two sets of plats were used so that there was a crop of wheat to harvest each year, making a fair and apparently honest comparison not only with the results between rotating with summer fallow or with corn, but of these yields against wheat continuously.

Seven consecutive crops of wheat on same field showed an average of 13.7 bushels. We wish to call attention to the fact that the rotation with corn or summer fallow only gave a gain of slightly more than two bushels per acre,

REAL SUMMER CULTURE.

We would also call attention to the manner of summer fallow, and as a comparison, note carefully our instructions under the heading of summer culture.

Compare the above results as taken from Bulletin No. 98, South Dakota Agricultural College, with the Pomeroy Model Farm at Hill City, Kansas, where the results after our plan of summer culture in four consecutive years, 1901 to 1904 inclusive, the average was over forty bushels per acre, while wheat in the same locality, grown under the ordinary methods of tillage averaged less than ten bushels. It will be noticed that the above four years included the very unfavorable seasons of 1901 and 1904, in which a large per cent of the wheat in that locality was a total failure. At Holdrege, Nebraska, which is 200 miles west of Omaha, the lowest yield of wheat rotated

with summer culture for three years has been 51½ bushels, and in each case the wheat tested 62½ to 64 pounds per bushel.

At Trenton, Hitchcock county, Nebraska, in 1904, where 90 per cent of over 20,000 acres of wheat sown was a total failure, a field having been summer tilled according to our plan, yielded 41 bushels of 60 pound wheat. We refer to these very marked contrasts between the results of wheat rotated with summer fallow and wheat rotated with summer culture to show clearly and distinctly that there is not only a difference in methods, but a very marked difference in results.

RESULTS OF TILLING.

At the North Platte branch station of the Nebraska State Agricultural College a piece of ground was summer tilled in 1904, sowed to wheat that fall with seed ranging from one-half bushel to one bushel per acre. The result of this excessive seeding was an enormous growth of wheat during 1905. The vast amount of fertility that was made available by the careful tillage of this field in 1904 resulted in an unusual amount of stooling, making the wheat altogether too thick, consequently straw was too weak; and before harvest time it all went down flat, and could not be cut with a binder, neither could it be cut with a mower. This crop was left on the ground, until the spring of 1906, when it was burned off and sowed to barley and yielded 62 bushels per acre. This in face of the fact that some plats fitted under the ordinary methods in the immediate vicinity and sowed to barley yielded practically nothing.

We could quote many similar results, but what seems a little strange is that we should have been farming in this country for more than a hundred years and yet no

one got onto the fact that by a little different method of handling the soil three and four ttimes as much grain might be produced.

We do not refer to South Dakota for any special reason, other than it is a fair illustration of work done by all the stations and shows very conclusively how easy it is to become wedded to theory and beleive it to be right, though it may be wrong in practice.

DIFFICULTY OF EXPERIMENTS.

Again we must repeat the fact that soil culture is one of the most, if not the most, complex science we have, for the reason that we cannot see what is going on in the soil below the surface. A certain thing done under certain soil conditions will produce certain results, while the same mechanical work under slightly changed conditions will not bring the same results at all.

Another serious drawback to rapid development along correct lines is the fact that twelve long months are required between each experiment. Then the experimenter may follow out the same line for three, five or ten years, and just as he begins to think he has established a point he finds that what he supposed to be the influencing element has practically nothing to do with the result.

We frequently find experimenters that have spent almost a lifetime on certain lines of experiments with confidence in the correctness of their position; then through some chain of circumstances find they are wrong and change their tactics entirely. To us it seems almost ridiculous for the average farmer to attempt to conduct any experiment in soil tillage with a hope of new and valuable light. Let him rather spend his efforts in proving what those with facilities have worked out.

Theory is one thing, a practical demonstrated fact is

quite another. What the farmer wants to know is how he can get the largest profit from his farm in a series of years. If he be a stock grower it matters little how scientific he may be in the handling and feeding of his stock—if his crop is short his profits are proportionately short.

AVERAGE GRAIN YIELD.

If he depends upon the sale of fodders and grains for profits, then his profits are very materially increased by even a slight increase in yield. For illustration, the average yield per acre of wheat for the following states for twelve years, 1893 to to 1904 inclusive, was: Illinois, 13.3 bushels; Minnesota, 14 bushels; North Dakota, 12.6 bushels; South Dakota, 10.2 bushels; Nebraska, 13.5 bushels; and Kansas, 12.3 bushels.

Now suppose a farmer raises about the average or 13 bushels, from this must come all the expense of raising, threshing, interest on land, investment or rental, wear and tear, or use of teams and tools, and when you figure up as above and balance your account there is practically nothing left for the farmer.

Thirteen bushels of wheat per acre is about one-fourth of the producing powers of any of the good lands in all of the above states, or any other similar lands, and less than one-third of the smallest yield we have gotten following summer tilling, where the work was properly done in any one year during the past seven years. Supposing that the farmer doubles the 13 bushels, the last 13 bushels is nearly all profit, except the cost of threshing and marketing. All that is necessary to get this increased yield is to get the soil into a more scientific or correct physical condition, and when this same amount of labor that was required to fit the soil for the 13 bushel crop is applied,

not foolishly and recklessly, but at the right time and in the right manner, there is needed but little more extra work.

Let us go a little further, and with just a little more extra labor, and only a little, put in scientifically, and we will get three times the 13 bushel yield or 39 bushels, and yet a little more labor and four times the amount, or 52 bushels can be grown. This has been done—yes, and as high as 63 and over—in several instances, and the 60 bushel point can be easily reached in many places, if the principles we shall outline are carefully followed. Think of it a moment—four and a-half times as much as the average of all these states for twelve years.

HOW SUMMER TILLING SHOULD BE DONE.

Begin the work as early in the spring as the frost is sufficiently out of the ground, and the surface dry enough to permit the use of the disk harrow without the soil adhering to the disk, going over the ground twice by lapping the disk one half. This produces a mulch which prevents evaporation; also loosens and opens the surface, so that the later rains readily and quickly percolate into the soil, harrowing the ground after each subsequent rain. If the rain is too heavy so as to dissolve and pack the surface, a second disking may be necessary, especially so if the season is advanced far enough for weeds to start freely. Don't at all hazards permit the weeds to grow or the surace to become crusted. A little carelessness here may and often does make ten or twenty bushels less yield in wheat, and proportionally similar losses to other crops.

Bear in mind there are three objects in conducting this work with great care. First, is to retain all the moisture possible that may be then in the soil, for the evaporation in early spring is very great from both the strong rays

of the sun, and in most localities the high spring winds take up much moisture. Second, is to loosen the surface that it may more readily and more surely take in all the water from the spring rains. Third, but by no means least, to admit the warm spring air that nature's laboratory may be put early to work preparing the way for large quantities of available fertility or plant elements. Plow late in June or early July, seven to eight inches deep. Do not leave the field at noon until that which has been plowed during the forenoon has been gone over with the sub-surface packer. Then at night the same, and if you use the packer follow it with some kind of a harrow or cultivator that will leave the surface with a light loose mulch, breaking the larger clods and leveling, so far as it may be possible, the top of the firm soil beneath.

The common lever harrow produces very fair conditions. There are, however, three or four much improved devices for this work being perfected, which will doubtless be found on the market very soon.

KEEP AHEAD OF THE WEEDS.

In June and July weeds are quite persistent and great care should be taken not to let them get the start. In fact there is but little danger of weeds if you take care to lose no water by evaporation. All weeds are easily killed when small, but after the tap root has gone down and become firmly imbedded, it is not easy to destroy them. Watch the condition of your field, going over it as soon after a heavy rain as the soil will permit, using the tool which you use to keep your mulch open and loose; care should be taken to keep the mulch from two and a-half to three inches deep. Remember, it is not desirable to have this mulch too fine, and never a dust blanket. It will be found very much easier to secure a

mulch of desirable coarseness, if the cultivating is done after rains when the surface soil has reached the moist condition, not wet, and yet before it gets dry. Continue this persistent care through the season; in case of extreme heat more frequent cultivation is necessary. Our rule is to watch carefully the firm soil just beneath the mulch and gauge our time of cultivation during continued dry periods by the quantity of apparent moisture, observed at the top of the firm soil beneath the mulch, or if we move the loose soil away and find there is ample moisture, the protection is all right. If the top is beginning to show dry, then it is time to cultivate again.

EARLY SPRING WORK.

If desirable to put in spring crops, it is a good idea to thoroughly disk the ground as it goes into the winter. This will bring some of the moist firm soil to the top and better protect from winds, also leaving the surface more uneven, to catch the snow, if in a country where snow-storms are looked for.

In the early spring, as soon as spring conditions will permit, the ground should be gone over for the purpose of reestablishing the soil mulch. Should the snows and rains have been ample to have considerably packed the surface, the disk harrow may of necessity have to be used, although much depends on the kind of a harrow or cultivator you may have. These are points of which the precise how cannot be specified; get the idea, then use good judgment as to the how and when, and the kind of tool.

In case of fall seeding to winter wheat, rye or oats, care should be taken, especially in the more arid sections where fall rains of any magnitude are less probable, to have at least two inches and a-half of fine loose soil on the

surface, and if the seed bed is made fine and firm, as above outlined, not more than one-third of the usual amount of seed is necessary. Under these conditions place the seed from a half to one inch into the fine firm soil, not over that, and by all means if you are getting a new drill, purchase the closed heel shoe drill or some drill that will leave the seed in firm soil.

SECURING IDEAL CONDITIONS.

Cut No. 16 represents the most ideal soil conditions and shows the effect of depositing the seed in its proper place, with the closed heel shoe drill, the principal advantages of which are set forth in the chapter on wheat growing.

While our methods of summer culture involve some little extra work over the old or more common methods of summer fallow or general preparation for crops; yet you must consider fully and carefully two points. First, that the object of summer culture is not only to store ample moisture below so that we may be able to carry our next crop through to maturity, no matter how dry the season may be without ill effect from the droughty condition, but further to provide and steadily maintain such an ideal physical condition of the soil during the entire spring and summer, as shall permit of a most liberal development of bacteria and nitrate or available fertility, in order that we may grow and mature a very large crop of whatever we plant, no matter what the season may be.

What we mean by a very large crop is, two and three times as much as the average farmer has been producing per acre by the old or more common methods. Can this be done? Yes; and we have proven it by repeated results each year during seven consecutive years; beginning with

the year 1900, increasing the certainty and magnitude of these yields as we learned more of the correct principles in detail.

CLIMATE NOT RESPONSIBLE.

It is altogether too common an idea that the quantity and quality of the crop depends upon climatic conditions. This does not apply to the semi-arid belt. The success of the farmer depends entirely upon the quantity and quality of the grains and vegetables he raises. Under the ordinary plan of farming the expense of preparing, planting and cultivating is just the same whether we get fifty bushels of corn or five bushels or none at all. If we proceed properly the necessary labor may be fifty per cent more, but even if it were double and we succeed in getting thirty to sixty bushels of wheat in seasons when our neighbors under ordinary conditions get five or ten, does it pay? If we are able to get eighty bushels of corn when our neighbor gets thirty, does it pay?

By holding the moisture near the surface during the heated portions of the season we succeed in securing a more complete decomposition of the vegetable matter in our soil, passing it on to the stage known as humus, which is a most valuable element in the soil. The more humus we have the greater amount of moisture we can hold in the ground. This, coupled with the amount of moisture that we are able to store, and the improvement of the physical condition of the soil by the disking, plowing and frequent cultivation in our summer culture, brings about four conditions By the very fine, compact condition, our soil will hold more water, consequently our plant is less liable to suffer from a lack of water during extreme heat. This packed condition is also, from the fact of the more minute pores in the soil, favorable to a more rapid

movement of moisture by capillary attraction, and last but not least, conducive to a more prolific growth, and a more general and uniform distribution of the roots.

Fourth, and by no means least, is the fact that under this condition of the soil, we are able to carry in the soil just the proper quantity of both air and water, which together with the heat, brings about that certain chemical action necessary for the development of the large quantities of fertility. When the pores in the soil are too large and soil coarse and loose, too much air is prevalent and little or no development of plant elements is possible. All four of these conditions are exceedingly important in seasons like that of 1901, when weeks go by with continuous extreme heat and no rain, and such seasons or conditions always come without warning.

POSSIBILITIES IN THE SEMI-ARID COUNTRY.

It is our opinion, based on practical results and observation of conditions similar to those in western Kansas that by the summer culture plan, storing the water the entire season and raising crops the following year, much larger average crops may be grown than the present average in Iowa or Illinois. In fact, we do not believe we overdraw when we say that in the more arid portions of the semi-arid belt, by the summer culture plan, only cropping every other year, we can raise more wheat at less cost in ten years than can be grown in the more humid portions of the belt in ten consecutive crops by the ordinary plan. By our method we have the advantage of only seeding half the land and only harvesting half the land. The great value of work along this line lies in grasping fully the idea of storing and conserving the rain waters, and studying carefully the necessary physical condition of the soil and endeavoring to bring it to the highest degree of perfection.

If water is stored in the soil of our western prairies, nature has formed perfect and complete conditions to bring this moisture back by capillary attraction to that stratum, or one known as the root bed, where it not only plays its part as drink for the plant, but as above stated to keep up its part in combination with other elements in the development of available plant elements, upon which the plant not only exists but thrives during prolonged dry periods, causing a prolific growth instead of withering and sometimes total failure under the coarser or more common conditions of the soil.

OF UNIVERSAL APPLICATION.

In fact, when the conditions are understood and the necessary labor properly applied, records of phenomenal yields will be numerous as far west as the foot hills of the Rockies.

The following from E. F. Stevens, of the Crete nursery, shows the value of summer culture, even in the more humid portions of the semi-arid belt. He says: "Regarding the possibility of carrying moisture conserved one year over into the next season for use for the next crop, we remember that one year we grew a crop of seedlings on elevated tahle lands on a part of the divide between the Blue and Salt creek, just southeast of Crete. Seedlings for their best growth require very frequent cultivation. They are cultivated weekly and oft times twice a week, to secure the best possible growth and the best grade obtainable in a few months. This superior culture conserved moisture, but we did not so understand it then. As a rule a crop of seedlings does not take up all the annual rainfall, so quite a portion of this conserved moisture was carried over until the next season. The following

year on this plat of ground previously devoted to seedlings, as above stated, we secured 105 bushels and forty pounds of corn per acre."

This marvelous yield referred to by Mr. Stevens is the direct result of the careful cultivation which resulted in storing a large surplus of moisture, and it is fair and reasonable to conclude that equally as good, if not better, results may be gained in any portion of Nebraska, Kansas, or western Iowa and Missouri, by following our plan of summer culture.

To get the best results the farmer's mind must be clear on three important points: That the ground must be in proper condition when all his work is done on the soil; that he must have a good, fine and firm root bed or seed and an abundance of moisture stored below.

A REMARKABLE ILLUSTRATION.

In closing this chapter it may be very interesting as well as very conclusive evidence of the correctness of our claims, to give a few of the very marked conditions that surrounded some of the fields of wheat in the spring of 1904 on the Pomeroy Model Farm at Hill City, Kansas, during the long continued early drouth. When most fields under ordinary methods of cultivation were showing no growth and no apparent moisture, the Model farm wheat was making rapid growth carrying a dark green color, while five feet of moisture was found below. Another field near Grainfield, Kansas, was in the same condition; another near Champion, Nebraska, and another near Trenton, Nebraska. The latter yielded forty-one bushels per acre, while ninety per cent of the entire wheat crop in that localitv was a total failure. Every wheat field in western Nebraska and Kansas might have yielded as much as the Trenton field had the land been treated

by our method and the heavy rains of 1903 stored in the soil and reserved for the long dry spring of 1904. Do not confound summer culture with summer fallowing. They are different.

Summer culture previous to seeding to alfalfa will insure a positive and even catch and a fair crop the first season.

Summer culture for the storing of the rain waters in the soil, although comparatively new as outlined, is a most important adjunct in farming in the West.

Begin your summer culture as early in the spring as the conditions will let you on the ground with your disk harrow. Don't let the weeds grow, thinking they are valuable as a fertilizer to turn under. The moisture they take from the ground is worth far more to you in growing the next crop.

The purposes of summer culture are many, but the most prominent of all that it never fails to bring about to a most marvelous degree is to change a field of very normal crop growing ability to one of almost incomprehensible producing powers in just ordinary seasons. So marked are the results that all sorts of doubting Thomases appear and present many theories, but we urge the student to throw away all skeptical influences. Study well the principles and apply them with as much correctness as possible and draw your own conclusion as to certainty of results and causes of results.

CHAPTER XI.

PHYSICAL CONDITION OF THE SOIL.

By the physical condition of the soil we refer to the proper preparation and that final condition of the soil that so completely regulates or governs its producing powers.

There is no subject less understood today and there is no one branch of agricultural science so vital to the success of the farmer as a thorough knowledge of soil physics.

The man who delves down into the very heart of this subject and follows every line and branch until he ferrets out all the dark secrets of controlling and utilizing nature's great resources now lying dormant in our great prairies, will do more for suffering humanity than any half dozen men have ever yet done.

It is our candid opinion that when this is accomplished, grain will be produced so much cheaper because of the greatly increased yield per acre, that bread will be provided at much less than the present cost.

Millions are being spent by the United States government in building enormous reservoirs and miles of expensive ditches, and millions more in scanning other countries far and wide for improved plants and seeds, but all this combined cannot provide as many prosperous farmers or cheapen the cost of production like the thorough knowledge of soil physics and soil culture.

It is appalling to think that we have so many men who know all about the soil and its tillage, or think they

do, and yet so very little has been accomplished in increasing the average yield of our great and magnificent prairies.

The average yield of all grains in Nebraska and Kansas in 1906 was from 15 to 30 per cent greater than any one previous year in the past twenty years. Many say this is due to more favorable climatic conditions, but this is not wholly true. A good portion is due to a better knowledge of the soils and how to till them; and yet it is possible by a still more comprehensive knowledge of these soils and what physical condition it is necessary to reach together with the how, when and where, to attain that degree that we may be able to liberate and utilize all natures' resources. We shall then see the average yield as shown in the above states in 1906, easily doubled, and what is true of these states is proportionately true of all other similar states. Why this subject, so vital to the the welfare of our country, has been so neglected in the past we cannot comprehend.

There will be some little gained by seed breeding and seed selection and a little by acclimating plants, a little by crop rotation, but not until rotation is better understood than it is now. Possibly some material gain may be made by the introduction of the so-called drouth-resisting plants. But the great and lasting change that is certainly on its way, must come through a broader and more practical knowledge of soil physics.

FORCES THAT AWAIT DEVELOPMENT.

Few tillers of the soil realize how easily the silent forces that lie beneath our feet within this inert soil over which we walk and have been taught to almost shun, can by timely direction and control be made to minister unto us by yielding up from mother earth bountiful crops. Sad

indeed it is that so many through a chain of circumstances have been led to look upon farming, especially the actual tillage of the soil, as wearisome toil, uncertain of its reward.

If they could be only made to see that kind Providence has intended that man should have dominion over all things, and set themselves at work to learn how they may intelligently command nature's resources that certain obedience may be secured, then toil would be changed to healthful, inspiring, agreeable work.

We wish to prove to you that nature has provided all necessary elements on these broad, level prairies of the semi-arid belt to grow cereals, vegetables, forage and fruits in such quantities and of such quality as to make the most sanguine minds marvel, when proper tillage is applied.

To do this the tiller of the soil must learn what to do; when to do it, how to do it, and why he works the soil by this method which enables nature to reveal all the possibilities she stores in this workshop for an unlimited supply of crop material. We will show you that it does not require a vast amount of hard and expensive labor to get large results, but it does require effort with knowledge and judgment. Just as a valuable machine may be made powerless and useless by the wrong or slack adjustment of some bolt or nut, so in the mechanical preparation of the soil success in the highest degree depends on doing the right thing at the right time and in the right manner. You could not put a valuable machine together unless you knew something of mechanics. You cannot properly till the soil and extract from it all that nature has stored there for your use unless you understand some of the simple rules of soil physics.

Much misleading matter has been printed on the subject of soil physics and in discussing available soil fertility. Professor Milton Whitney, chief of the bureau of soils, United States department of Agriculture, says in Bulletin No. 22, issued by the department, "That there is no apparent relation between the chemical composition of the soil as determined by the methods of analysis used, and the yields of crops; but that the chief factor determining the yield is the physical condition of the soil under suitable climatic conditions."

It is our candid opinion, based on more than twenty years' of observation and experience, that it is to the highest interest to the farmer to give little attention to the chemical properties of his soil until he has learned well and carefully its necessary physical condition in order that he may utilize nature's many elements and forces found in the soil, also in the air, water, heat and light.

The general properties of the component parts of the average high level prairies of the semi-arid belt are all that could be desired. In the cultivation of these soils every precaution should be taken to prevent at any and all times during the year any loss of moisture by evaporation. It is highly important that these soils never be allowed to dry out. Upon this fact depends much.

Roberts in his book on the "Fertility of the Land," says: "The percolation of rain waters not only conserves the plant food but improves the physical condition of the land. Just as soon as the soil becomes depleted of its moisture it becomes dead or dormant and life ceases."

TIME TO WORK THE SOIL.

In order to secure the best possible physical condition, the greatest care should be exercised to do the plowing, packing and cultivating while the soil is moist. When the

soil is moist, as all observing farmers know, the soil grains more readily separate one from the other. The real or desirable object of plowing is not simply to turn the soil over, but in addition to turning the soil is the pulverizing The more thoroughly this is done the better opportunity the heat, air and moisture have to exercise their full power to combine all the properties into plant foods so that they may be available to the plant.

So far as we can grasp the true principles regarding the necessary physical conditions, they are found in recognizing the following facts, viz:

First—That fertility is not matter, or a substance, or something that exists in the soil in given quantities and makes plants grow if the seed is put in the soil, regardless of how it is tilled or fitted.

Second—That the growth of all plants dependsp uon the quantity and force or energy of the available fertility, and this is great or small just in proportion to the physical or mechanical condition of the soil.

Third—That the soil is nature's laboratory, where the proportion of air and water may be combined in just the proper quantities. If the soils are too coarse and lie too loose, then there is too much air for the water the soil can hold, and with the most ideal climatic conditions only fairly good crops can possibly be grown.

Fourth—That water is a vital element in all vegetable growth, but it is not the only element that the tiller of the soil must see to. Air is equally important, and in all tillage, air must be recognized and the soil prepared with an eye to utilizing it just as nature demands. Give nature a chance and she will do wonders, but don't expect too much without some intelligent effort on your part.

The plants under proper conditions show a dark, healthy green color, and grows rapidly. Remember that the root growth in all grains is always in excess of the plant above ground, and that root growth is greatest in soil that is fine and firm in which there is held all the moisture than can be carried by capillary force, and that it is apparently impossible by ordinary mechanical work to get the average sand loam soil in the great semi-arid section so firm that it cannot carry at the same time the necessary amount of air.

PERFECT SOIL CONDITIONS.

Let us assume for further illustration or explanation that we have just the ideal condition for holding and carrying the proper quantity of air and water in the soil. The sun is warming the soils, chemical action is doing its work, the wheat, oats or barley is three or four inches high, a rain comes of some little magnitude which dissolves and packs the soil mulch on the surface, then the sun comes out and the plants improve for a little time, but at this point look out, for we are approaching the danger point, not of the total loss of the crop but of getting the highest possible yield, which should be our aim at all times.

If by certain more carefully fitted soil conditions, you can get 50 bushels of wheat per acre instead of 10 to 20 bushels per acre, is it not worth digging for?

This is no visionary or imposible thought, but a stern truth, that only requires a little careful study and intelligent application, after first stepping away from those old, stubborn prejudices, that theory alone had prompted you to cling so tenaciously to.

The packing of the surface by the rain will cause an

upward movement of moisture which is brought from the root zone or stratum by capillary attraction to the surface and evaporated.

The warm sun has set the vigorous plant to work pumping water by means of its many little rootlets up through the stalk and out the leaf. With these two forces at work your moisture is soon depleted below the normal, and chemical action becomes slower.

Another dangerous factor is also at work, the moisture that is rising to the surface is carrying with it the magnesia, alkalies and salts so prevalent in our prairie soils, in a soluble or dissolved condition, and as they reach the surface the moisture is lost in vapor.

These mineral substances are deposited between the surface soil grains, and if this process goes on long enough the surface becomes solid and the air nearly or quite excluded. The moment this condition becomes general practically all growth ceases from a lack of air though there may be plenty of moisture. Therefore the vital importance of harrowing this surface as explained in other chapters.

The Cut No 9 on page 76 illustrates quite clearly the ideal physical condition as compared with the more common haphazard manner. Study the two views carefully, and think of what you have seen in the field and how different were the results.

It is our opinion that upon this ideal physical condition of the soil grains as shown in the above cut, as well as others shown in previous chapters, depends very largely the magnitude and quality of the crop. This conclusion is not based on theory, but upon results obtained in many tests following these lines.

We have invariably found growth most rapid and the plants most healthful when the soil was fine and firm where the roots were growing, with the surface two inches or more loose and open, and ample moisture stored below to a depth of four or more feet, and this so long as there is the required quantity of air and water in that portion beneath the mulch where the principal feeding roots are located. By the aid of heat chemical action is going on and fertility is being made available in large quantities. Now the great point is to keep up this kind of condition, if it can be done through the growing season. Phenomenal results are sure to come, if there is not too much seed, or some fungus or insect pest at hand. Too much seed is very commonly the cause of a yield below the possible result on soil ideally fitted and especially is this true of oats and wheat.

CHAPTER XII.

SOIL FERTILITY.

That which every farmer tries to do is to cause his land to bring forth good crops. All his labor leads up to the harvest time. His whole reckoning is preliminary to market results.

So it is that when the farmer or the home seeker goes out to consider whether he shall buy a given tract of land, the question that is uppermost in his mind relates to the crop producing qualities of the soil. Everyone knows that some soils are better than others and that there are soils which seemingly are not of any use at all in crop production. Then it is also fairly well known that land cultivated in the best possible manner may become better with the years, while land poorly cared for may rapidly lose what little value it had in its wild state.

The ordinary or average tiller of the soil has very little knowledge of the scientific principles which are involved in this distinction. It is not surprising, either; for as a matter of fact, those who have made a specialty of the scientific study of soils, who have spent much time and money in experimental work, and who have been able to collect the information brought out by hundreds of others who have gone before—these specialists are not at all agreed as to very many of the essential points in regard to the soil. The best of these are quite prepared to modify their views at any time.

With the scientific investigations we have little concern. It is with results that we have to deal.

This fact must be kept in mind that, speaking in every-day terms, there is a distinction between fertility and available fertility. Perhaps it is better stated that the only kind of fertility that the farmer cares for is that which is available, and he has little concern for any fertility that is supposed to rest within the soil unless he possesses the secret of making it useful in increasing his crop yield. So it is that in speaking of fertility we wish to be understood as referring to available fertility.

A CONDITION OF THE SOIL.

Soil fertility is not something that is a part of the soil. A very good soil may have little or no fertility available. It is a thing apart from the soil, to be placed there or to be developed there, through a condition of the soil due to a combination of causes. And it is just to bring about this condition that the farmer tills his land. The purpose we have in scientific soil culture is to develop fertility by and through creating within the soil a condition favorable to this development. The reader will find in this Manual a great deal about the treatment of the soil to conserve the moisture and to give it the proper amount of air, and to guard against drouth, and to keep the soil's physical condition right—all looking to development of soil fertility.

That soil fertility depends a great deal more upon the condition of the soil than has been commonly believed is now coming to be accepted by many of those whose positions entitle them to consideration. Prof. L. H. Bailey, of the Cornell University experiment station, a man always fair and always in the front rank, has declared that "the texture or physical condition of the soil is nearly always more important than its mere richness in plant food." In explaining why a finely divided, mellow,

friable soil is more productive than a hard and lumpy one of the same chemical composition, he says that "it holds and retains more moisture; holds more air; presents greater surface to the roots; promotes nitrifiication; hastens the decomposition of the mineral elements; has less variable extremes of temperature; allows a better root-hold to the plant."

And as if to clinch the matter Prof. Bailey in briefly referring to fertilizers, declares that "it is useless to apply commercial fertilizers to lands which are not in proper physical condition for the very best growth of crops."

SAVING OUR SOILS.

In a circular issued by the University of Illinois relating to soil investigation, Prof. Cyril G. Hopkins asks these pertinent questions:

"Does not the ultimate position or final destiny of America rest upon the question whether the crop producing power of our soils shall continue gradually to be reduced or whether it shall be increased or at least maintained? We need not ask whether the fertility of the soil can be absolutely and completely exhausted. The fundamental question is, will the system of farming which we practice or advise ultimately reduce the productive capacity of the soil."

And in prefacing a somewhat breezy and certainly very instructive lecture upon the subject Prof. Hopkins says:

"Surely there is no subject pertaining to agricultural science and practice regarding which there is such a diversity of opinion as the subject of soil improvement for increased crop production. Both practical farmers and even eminent scientific authorities disagree almost absolutely on some fundamental principles. Indeed these

differences of opinion are so marked and frequent that I feel compelled to ask, in language which has recently been declared grammatical, 'Where are we at?' "

Prof. Hopkins evidently sees what is ahead, for he declares that "the agricultural experimental stations are becoming more and more responsible for the methods of soil management which are being practiced in this country," and he suggests that if leguminous crops, for instance, do not obtain sufficient atmospheric nitrogen, "is it not our business to discover why they do not, and then advocate a system of soil treatment or soil management which shall enable legumes to obtain from the free and absolutely inexhaustible supply of the atmosphere all of the nitrogen which they need for maximum yields?"

We make these quotations here, in connection with this subject, largely to make it clear to the average farmer that he need not feel at all discouraged if he realizes how little he knows about the mystery of the soil in its relation to plant growth. There are others in the haze.

CHANGING THEIR VIEWS.

Turning to Farmer's Bulletin 257, by the U. S. Department of Agriculture, containing an address on "Soil Fertility," by Prof. Milton Whitney, the eminent chief of the Bureau of Soils for the Department, we find him declaring that "fertility and crop production are different terms," and that "fertility is a property inherent in the soil; it is what the soil is capable of doing if it is under the best possible conditions." Of course Prof. Whitney presented the matter from a purely scientific standpoint, and his discussion of the soil and its purposes and of the feeding of plants by the soil was backed by years of investigation; yet we find him confessing with a frankness that is decidedly encouraging. He says:

"I believe that through the results of our investigations during the last twelve years we are beginning to understand clearly the chemistry of the soil. It is exceedingly interesting, but it is entirely different from our former conceptions of it. We are changing our ideas about the chemistry of the soil as we are changing our ideas about the nature of diseases and about physical forces and physical laws which we thought were perfectly understood."

It need not be regarded as at all surprising therefore, that practical farmers and experimenters should be changing their views as to the chemistry and the physics of the soil, and in regard to soil management, since those who have had such opportunities for knowing the truth admit now that their views are changing because of modern investigations.

And this is true that investigation is giving us new light on the soil and on the nature of soil fertility, and we are finding out a great many new things about the relationship which a certain physical condition of the soi through cultivation bears to the fertility of the soil and to plant growth.

The soil is not alone the home of the plant and a place for its roots to take hold and keep the plant erect; the soil is the source of food supply for the plant, and the supply is there in proportion to the intelligence of the tiller of the soil in his preparation for it.

Instinctively, almost, the possessor of land that is poor in crop producing qualities turns to fertilizers as his hope. But he often discovers that he has not been able to secure soil fertility by the application of fertilizers. He is puzzled, but he does not find any solution to the puzzle. The Department of Agriculture reports experi-

ments on a tract of land in Iowa "which with stable manure every time produces a smaller crop than without." No explanation.

WHAT THE SOIL IS.

Now the soil is, in fact, a part of the volcanic matter which composes most of the earth. It is broken into minute fragments. These fragments are perfect specimens of rocks and stones or pulverized minerals. But they are so fine that the different minerals readily combine by chemical action. The plant food is organic in nature. It is composed of different mineral substances united by chemical action or otherwise. We do not know and we never can know just how and why these combinations are effected.

We do know that nitrogen plays a large part in forming these organic substances which are the food of the plants. We know that nitrogen abounds in the air and that it may easily be separated from the other component parts of the air. We know that this chemical action is possible only where there is water, and we know that it is promoted by the rays of light from the sun. We feel sure also, that in some way the electricity ever present in the earth and in the air plays a part in this laboratory in developing growth.

What we can do by cultivation of the soil is to bring about the conditions best suited to whatever action is necessary to develop plant food in the soil. The ideal soil condition is one where there is just the right amount of water and air and other elements. We can do a great deal in assisting nature, or at least in not obstructing nature, in this laboratory work. And this is scientific soil culture.

The scientific investigator does not go far in making

explanation of the way soils gain fertility until he uses the term "bacteria." It is a useful term, and has a meaning fairly well understood, but the term is made to cover a good deal that is simply so mysterious that no explanation is offered. It is a fact, however, that the development of bacteria in the soil bears close relation to its fertility, and that these bacteria, whatever they may be in fact, play a very important part in making the soil what it ought to be for the greatest amount of plant food.

ELEMENTS OF FERTILITY.

There are several things in this connection that may be regarded as well settled.

1. Soil fertility is due to the proper combination of elements in the soil.

2. Soil fertility is developed in the soil by the proper tilling of the soil, so as to have available the right proportions of air, water, and other elements.

3. Soil fertility is possible to a high degree in almost every soil, and the addition of fertilizers is only one way of gaining this condition.

Again we repeat that all the processes of agriculture look to development and maintenance in the soil, of this available fertility which is so essential to plant growth. The farmer must bear this ever in mind. He turns over the sod or the stubble, not merely to pulverize the surface for a seed bed, or to kill the weeds, but he does it with a view to creating a physical condition of the soil suitable for development of fertility. He may never know why the mineral elements combine just as they do to make plant food, but it is enough for him to know they do it, then to do his part in preparing the way.

Good crop results from our fields is our great desire,

and to this end we have spent nearly a quarter of a century in soil culture experiments, study and general observation.

In 1891 we became positive of our ability by observing certain physical conditions of the soil to secure good crops during drouthy condition, while others failed; a little later we were convinced by repeated results that the average yield of the great semi-arid section even in good seasons could easily be doubled, and now it is evident there can be even a greater increase in the yields and to the development of increased available fertility by utilizing more of nature's abundant resources, such as heat, air, water and light through chemical action which we have found is great or small, just in proportion to the ability of the soil to combine these elements in proper quantities under such ideal conditions as shall cause the most complete chemical action for the production or development of the necessary amount of fertility, and that this all important ideal condition of the soil can be established by scientific soil culture.

CHAPTER XIII.

WATER HOLDING CAPACITY OF THE SOIL.

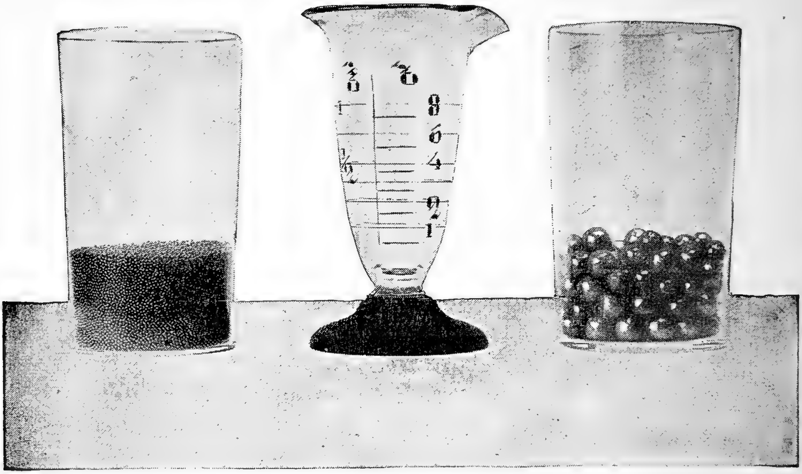
Among the more important questions involved in Scientific Soil Culture, is that of so handling and preparing the soil that it may carry the largest possible amount of of capillary water, and at the same time let surrounding conditions be such that all free or surplus water may readily percolate down and away.

It must be understood that a soil saturated or full of water is as bad as no water at all, so far as plant growth and the development of plant elements or fertility may be concerned.

It is now quite apparent that plants really do not utilize or consume the amount of water once thought necessary; in fact, some irrigation experiments have shown that beyond a certain nominal quantity of water, more water does not mean more or better crops. In these experiments and all others every result apparently points to the fact that there must be a certain quantity of water in the soil together with its requisite amount of air properly distributed and mingled, and when this very ideal condition is attained the only needful is Old Sol's persuasive influence, when the development of plants and fruits will be marvelously pleasing.

It takes no argument to convince the average man that there are many times when, if the soil could have had just a little more available moisture, there would have been one, two or three times as great a yield. To more

clearly show the vital importance, in this great semi-arid belt, of thoroughly fining and firming that portion of the soil in which the roots of the plants should grow and feed, we have prepared the accompanying illustration.



Cut No. 10. Water-holding Capacity of Soils.

In the glass on the right is one pound of the largest buckshot we could find; in the glass on the left is one pound of the very smallest bird shot we could obtain; in the center is an one-ounce druggist's graduate. With this graduate we measured precisely one ounce of water and turned into each glass. We then shook each glass to be sure that every shot was moistened all over. This covered each one with a thin film of water exactly as the moisture is retained around each little particle of soil. It is not possible in our illustration to get rid of the free water, or that portion between the shot, except by tipping the glass over and holding the shot back to allow all the water,

which is not held in film form, to drain out into the graduate. Measuring carefully the amount from each glass, we find to our surprise that the fine shot retains nearly thirteen times as much water as the coarse shot. Here we have a practical demonstration of how the water-holding capacity of the soil is increased by finely pulverizing and making it firm, a condition most favorable for the movement of moisture by capillary attraction and the most perfect development of roots, both of which subjects have been taken up in detail in other chapters.

The shot, before it was put into the glasses, was carefully weighed on fine druggists' scales to be sure that we had the same quantity. As you see, both glasses are filled to the same height with the coarse and fine shot and both glasses are of the same size.

WATER AND SOIL CONDITIONS.

The great question which bears so largely upon the quantity and quality of all crops is that of water in sufficient available quantities at all times. Nothing has more to do with this than the mechanical or physical condition of the soil. The deeper the soil is stirred and yet made fine and firm, the greater is our ability to guard against the shortage of water at some critical time. To plow deeply and leave the under portion lumpy and loose is a very objectionable condition with which to approach a dry period, and as experience has shown, no one knows when such a time may occur. Therefore, for safety, the lower portion of the furrow must be made fine and compect, as deep as plowed.

Many thinking men, from a theoretical standpoint, insist that the soil of the prairies must be loosened up deeply to let the water down. This is not essential in the least, providing the soil is moist a foot or so below the

surface and the surface is kept loose. As soon as the rain comes in contact with the moist earth below it readily percolates down through the fine soil. In fact the soil that is moist for three or four feet down will dry off on the surface much quicker than soil that is dry underneath because of more rapid percolation. The slowest soil to take the rain waters is the dry soil with a firm surface.

Again considering the water-holding capacity of the soil, and recognizing a marked difference in the amount of the water held by the fine shot shown in our illustration, we more clearly grasp the value of adding well rotted manures to the soil of the western prairies and the further importance of having it thoroughly mixed into the soil. The manure when decomposed very materially adds to the number of minute particles and further increases the water-holding capacity. The manure question is fully considered in a chapter by itself, and should be very carefully studied for its relation to the moisture question is broad; therefore, it is one that means much to the semi-arid country.

CHAPTER XIV.

IMPORTANCE OF AIR IN THE SOIL.

Not as much importance has been given to a study of the part played by air in the soil as the subject warrants. Neither is it very well understood that its availability in the soil is largely regulated by the mechanical arrangement of the particles in the upper six or eight inches top layer of the soil.

Because we have seen it constantly demonstrated we know the necessity of water in the soil for plant growth, but it is not so easy to comprehend the material value to the plant of air in the soil. We cannot see its effect in anything like as broad a sense as we do the water, yet its presence in proper quantities in the soil and about the roots of the plants is just as vital to its life, health and growth as water.

Water without air and its component parts is worthless; air without water and its component parts is equally valueless to the growth and development of all farm crops.

Consider the subject carefully. How many times have we seen a field of wheat, corn or oats, possibly half-grown, and noted that in some depression the crop was ranker in growth and also a darker green. If a rain of considerable magnitude comes, and the depression fills with water and remains there for several days, the plants that seemed to have the advantage before the rain now begin to lose their dark, healthy green color; if the water remains long

enough over the surface a yellow cast becomes apparent, then a brown, and finally it dies. This is because of a lack of air at the roots.

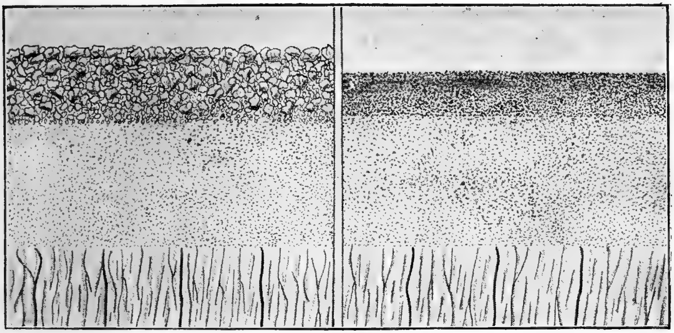
The great store house of nitrogen is the atmosphere. It is the place where all is kept that is not in use otherwise. And nitrogen is one of the essentials of plant life. The plants do not take their nitrogen directly from the air; but it comes to the plant in an indirect manner through organic substances in the soil. The nitrogen of the air combines with mineral substances in the soil, and then by reason of the action of bacteria certain compounds are formed which contain nitrogen in a soluble form. Then it becomes plant food.

NITROGEN AS PLANT FOOD.

But you cannot have these compounds containing nitrogen if the other elements are shut off from contact with nature's great storehouse of nitrogen. Hence the circulation of air in the soil is an absolute necessity. Soil in a perfect vacuum is dead soil, and can no more become or develop plant food than soil submerged in water or soil baked to absolute dryness.

The great danger in handling soil in relation to the air in the same lies in the possibility of having a condition that will shut out the air without the farmer knowing it. A heavy rain may produce this undesirable condition. In cut No. 11 is shown what frequently happens and how it may be overcome. It shows soil where there has been a heavy rainfall, beating down the surface which has been softened by the raindrops, and with the result that the upper surface is compacted perfectly. As soon as the small amount of water near the surface has disappeared by evaporation the upper crust is hard. It is impenetra-

ble by air. It may as effectually seal the subsoil from the air as does the coat of paraffine over the jar of jelly in the pantry.



A B

Cut No. 11. Showing Heavy Rain Crust and how it is Broken up (a) Soil Mulch Restored by Cultivation. (b) Soil Mulch after Heavy Rain, Dissolved and settled down.

When such conditions are found they must be destroyed. The only thing is to promptly break up this crust and put the soil into condition so there will again be a natural mingling of the air and water with the particles of the soil. This mingling must be in proper quantities of each—that is the soil must be of sufficient fineness and firmness below the surface, or that portion properly termed the root bed, so there may not be too much air, for while air is most valuable in the soil in just the proper quantities, it is seriously detrimental in too large quantities.

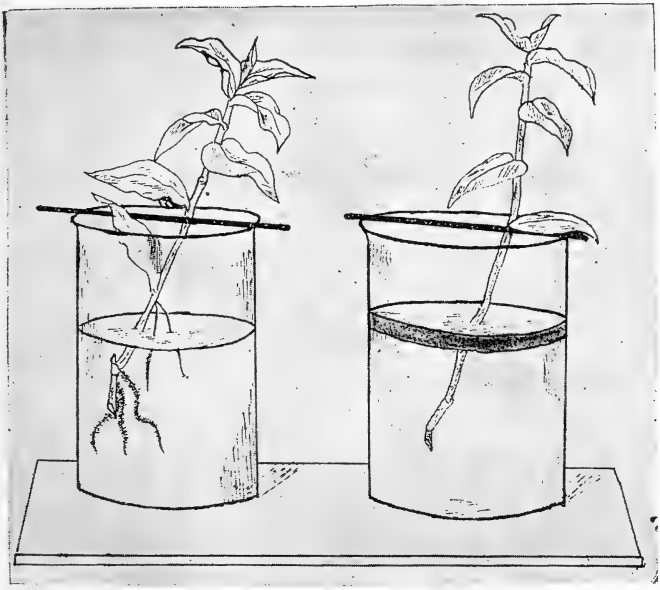
SHUTTING OUT THE AIR.

In the experiment work we have conducted we have noted some remarkable conditions and results. We have found, for instance, that the air may be shut out by the

forming of an almost impervious crust, either on the surface or beneath a soil mulch. The most marked effect of this crust was brought out at the Pomeroy model farm, Hill City, Kansas, in 1901, during an extremely long dry period in mid-summer when for nearly three months almost the entire country experienced one hundred degrees of heat, at times the thermometer running even higher, without any rain. Because of wheat harvesting and other pressing work the orchard was left from fifteen to eighteen days without cultivation. During this time a crust had formed under the mulch which we had kept fully two and a-half inches in depth. The crust was nearly one inch thick and was so dense that the air was almost completely shut out. This crust was caused by the mulch becoming so heated through the direct rays of the sun that the moisture in the firm soil just beneath formed a vapor and passed off through the pores of the mulch, to a degree moistening the mulch, and allowing enough capillary attraction, which together with the heat, permitted much of the moisture to be lost by evaporation. This resulted in bringing up much magnesia, alkali salts, etc., in a soluble or dissolved condition. When this soluble matter reached the point in the firm soil near the surface, where the moisture was transformed into vapor by the intense heat, it became a solid, and these minute particles gradually filled up the pores in the top of the firm soil.

Our attention was first called to this on returning after an absence of four days from the farm, by noting the fact that the foliage of the tree was losing its dark green color. To ascertain the reason for this, after finding that there was ample moisture beneath the crust, the experiment of double disking one-half of the orchard was tried. The disk was set to cut as deeply as possible, thus com-

pletely destroying the crust. On the morning of the fourth day there was a perceptible difference in the color of the leaves in this half of the orchard. In seven days the trees in the disked portion had resumed their healthy dark green color, while the undisked portion had become still lighter in color. The balance of the orchard was then disked. Although the extreme weather continued



Cut No. 12. Showing Effect of Shutting Air from Roots

four weeks longer, the leaves of the whole orchard resumed their fine, deep green, and new growth was apparently rapid.

Similar conditions have since been noted in wheat.

oats and corn, with same results from similar treatment, all pointing to the fact that both the growth and yield of crops may be very materially diminished by shutting the air from the roots of the plants.

To illustrate more fully the effect of shutting the air from the roots we take the accompanying cut No. 12 from Goff's book, "Principles of Plant Culture."

To make this test practical, two glasses were filled about half full of soft water, then two slips of the same kind of a plant as near alike as could be selected were placed in the two glasses and then a thin layer of olive oil was put upon the water in one glass to prevent the air reaching the water, the glasses placed in a warm light place; in a very few days live healthy roots are seen developing from the slip in the glass without the oil, while the oil covered glass not only shows no roots but the leaves soon begin to wither. While it must be remembered that slips from any and all trees or shrubs will not do this, only such as willow, nasturtion, or wandering jew, etc. Yet it demonstrates clearly and beyond a shade of doubt that the air plays a very important part in the growth and development of roots and plants.

One more thought before closing this very important topic. The full and complete knowledge of the relation of air and its utility in the production of all farm crops means the absolute certainty of the greatly increased yields of your fields without any material increase in the cost of production, because it is found in utilizing what is actually going to waste, not by a specially increased amount of labor, but through doing the work commonly done with an eye to bringing about that certain necessary physical condition more through a little different manner of tilling the soil when it is in proper condition to work.

CHAPTER XV.

PERCOLATION; OR GETTING WATER DOWN INTO THE SUB-SOIL.

During the past three years the question of getting the water down into the subsoil has commanded much attention and discussion.

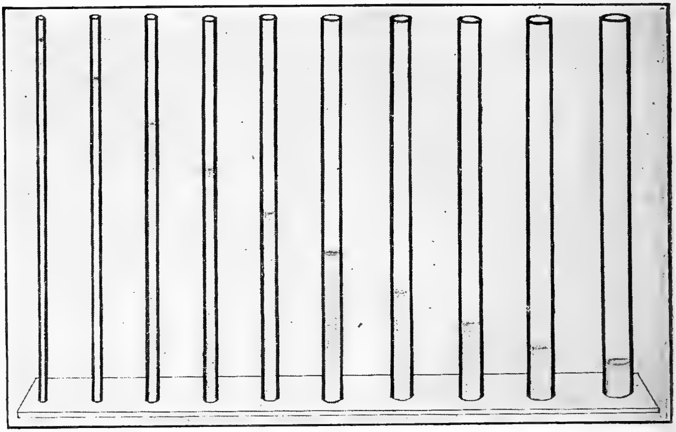
In the more arid sections there seems to be a prevailing idea that the soil must be broken up or loosened deeply by subsoiling or otherwise, or the rain waters will not permeate the subsoils of our great prairies to any material depth. Theoretically, this is true, and all general observations so far as the prairies in their natural state is concerned, have backed up the theory as a fact or truth.

A little broader and more careful observation shows the theory to be a theory only.

What we have found to be true in cultivated soils is also largely true of the prairies. Several trips over portions of Eastern Colorado in the autumn of 1906 gave strong proof that when the soil is moistened to a depth of one foot or more, that a subsequent rain of any magnitude soon disappears by percolation. This was proven in one instance in November; a quite heavy rain disappeared from the level prairies very quickly, although it remained cool and cloudy, so that little was lost by evaporation. Four days later showed the prairie soil to be moist nine inches deeper than before the rain; proving the readiness of moist soil to take in more water.

There is no subject that is more vital to the scientific

farmers in all our arid countries. To grow good crops successfully in any and all seasons, the moisture must be stored in the soils and subsoils below. If it is only a question of getting a living out of the soil, that is one thing, but if it is a question of living well in good homes and educating a family of children, then let us



Cut No. 13. Capillary Attraction Illustrated.

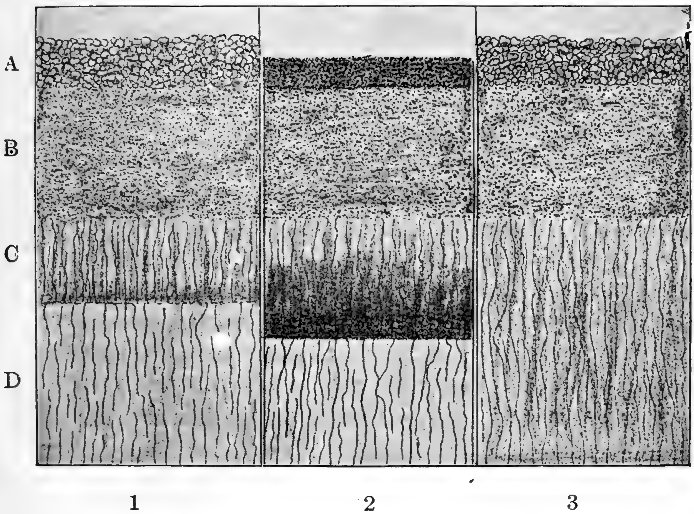
get out of the soil all we can. If we have a legal right to the crop that grows on the land we till then why not raise a big crop instead of a small one?

In cut No. 14 we have attempted to illustrate the percolation of water, or the getting of water down into the soil. We have divided this cut into three sections, numbering them 1, 2 and 3, from left to right, then divided these sections into lateral strata A, B, C, and D.

In section No. 1, A represents the soil mulch, a stratum

of light, loose, and dry soil; B represents a stratum of thoroughly pulverized and firm soil, meaning the portion that is cut by the plow and then sub-packed; C represents about eight inches of the subsoil into which water has percolated, and D represents the portion of subsoil still below that is yet dry.

In section 2, we find the mulch has been compacted by a heavy fall of rain. This mulch in its loose condition readily takes in the water, and as soon as the water reaches the moist soil found in strata B and C, it immediately



Cut No. 14. Showing How Water is Stored in the Soil.

percolates down below, and is shown by the darker portion of soil in the upper part of stratum D. Here the water has come in contact with dry soil, which resists percolation. Slowly and steadily by gravity the water finds its way

down the columns of soil, which by the way, throughout the entire semi-arid belt are almost invariably found in a perpendicular position.

In section 3, we have again reproduced our soil mulch by cultivation to stop the evaporation or loss of our water from the surface, and we find the moisture below has percolated on down until the water is all distributed, each little particle taking on its film of water to a given thickness which it seems to steadily hold onto while the balance of the free water finds its way on down until it is all distributed in like manner.

The next rain will result the same as is shown in section 2, only we have six, eight or twelve inches more moist soil for it to pass through before reaching the dry soil.

An illustration will make this more clear. In setting out our cabbage or tomato plants in the spring of the year when the surface is dry and fine we usually water them. In our first application of water to this dry surface we notice the water does not seem to percolate, but for a little time remains dormant on the surface. After a little it finds its way down through the dry particles by force of gravity, leaving each particle it passes covered with a thin film of water. Then we apply a second application of water while the surface is still moist and we notice the water immediately disappears. The reason of non-percolation of the first application is because of the resistance of the dry particles to moisture, or repulsion for water. The quick movement of the second application of water into the ground is the result of the attraction of water for water, together with gravity.

The following will illustrate this natural law: take a piece of glass, or a smooth earthen plate and oil it slightly, then put drops of water, a half dozen or more, on the glass,

take a narrow piece of ordinary newspaper, about one-half inch wide, let it extend from the thumb and finger about two inches, slowly move it down so the end of the paper will come in contact with a single drop of water. If you notice closely you will see a remarkable resistance of the paper against the water. Very soon the little pores begin to absorb the water, and the end of the paper becomes moist. Now slowly raise the paper and notice how persistently the paper hangs to the water. When it lets go there is a quick upward movement, thus showing the power of attraction of water for water. Now steadily move the fingers down slowly, watching the paper and you will notice when it gets close to the water there is a sudden movement down, even while there is a little space between the moisture on the paper and the water on the glass. The power of attraction is made very perceptible by the quick connection of the two moist particles. Now draw the paper across the glass from one drop to the other, you will notice the water all hangs together. You will have a string or train of water two or three inches long trailing on behind your paper.

This illustrates how easy it is to get moisture into the soil by keeping the surface constantly loose and open, so that as the rain falls it soon works its way through the larger pores until it reaches the moist particles in the firm soil, when it immediately percolates on down below. Here again nature has done a great deal for the semi-arid belt. The peculiar formation and size of the usual particle of soil is very favorable for percolation; also for its return upward by capillary attraction to feed the plant during our long dry seasons.

Here again we must reiterate. When a heavy rain comes, the effect is to more or less dissolve the soil mulch

and cause it to settle very firm as shown in the center column of our illustration. The restoring of this mulch is of vital importance, and the question of the proper time in which the condition of the surface soil regarding the per cent of moisture it still has, must be carefully considered, that cultivation may be done at a time when the greatest good may come from it.

When we realize that under the conditions we are considering, following a heavy rain, the soil will lose from its surface by evaporation under normal summer climatic conditions from one and a-half to two quarts of water per square foot each day.

We certainly should grasp the importance of quick action, but if we cultivate too quickly we may puddle the soil and leave a very poor mulch, especially if the soil be close and heavy.

Again if the soil be slightly or quite sandy and we delay the cultivation too long, and the surface soil becomes quite dry, which it will much quicker than the heavy soil, then we may have our soil too much on the order of dust which is easily disturbed by high winds. All these things must be watched and duly considered.

Just as soon as the soil is dry enough so it will not stick to the harrow or cultivator, it should be quickly gone over.

CHAPTER XVI.

EVAPORATION.

In connection with the percolation of the water down through the soil and the capillary movement of the water upwards, there is the all-important topic of evaporation.

It is highly important to the farmer living in the semi-arid region to know all about evaporation, for it is by evaporation rather than by under drainage that the larger part of his water leaves him.

When one understands perfectly the effect of evaporation and how it operates to remove water from the soil he is in a position to better understand why it is that there can be so much conservation of the moisture in the soil that the land of the semi-arid belt becomes in fact better fitted for good crops than the land of the more humid sections. It is a common remark among those who but little understand the situation that if there was only a little more rainfall in the semi-arid region it would be the ideal farming country. They say that all the country lacks is enough rainfall to provide all the water necessary. This is a superficial view. It does not take into account the main elements.

It is true that if we could always have here in the semi-arid country just the right amount of rainfall, and have it at the right time, we would have no trouble in raising good crops. It would be very nice indeed to have this condition. We would have the tropics beat badly, and our people would have time for bull fights and things like that while they were just waiting for the crops to mature.

But it is also true, and this needs no demonstration, that even in the humid sections of the country they suffer from drouth. Down on the Atlantic coast there are many places where there is an average of one rainy day in every three during the growing season—and right there you will find the old settlers telling about how they lost a crop by drouth. And if they do not suffer from drouth they are likely to suffer equally as much by having rain when they do not want it.

RAPIDITY OF EVAPORATION.

It is stated that the best estimate based on experiments as to the extent of evaporation from the soil in the humid regions shows that fully fifty per cent of the rain water which falls is returned to the air directly in vapor. But this is not true of the semi-arid region, where a much smaller proportion is returned to the air in that way. And where there is cultivation with a special view to preventing this evaporation from the surface the evaporation is still less. Prof. Whitney tells of an experiment by the Department of Agriculture to test the rapidity of evaporation under different conditions. Two cylinders six feet long were filled with soil and placed erect in water so that the soil was kept damp. Then over the exposed end of one tube a draft of air was blown to hasten evaporation, while over the other a similar blast of air was blown, but in this case the air was heated. It was evident that the heated air would of itself take up the water faster than the cold air. For a time the evaporation from the tube where the heated air was operating seemed to be much faster than from the other. But the surface soil was soon dried out and this checked evaporation. During the time the experiment was conducted it was found that the evaporation from the tube with heated air was very much less than from the tube with cold air.

This illustrates exactly what is done on the soils of the semi-arid region to check evaporation.

NOT LACK OF RAINFALL.

The real difficulty in the semi-arid belt is not a lack of rainfall, but the loss of too much by evaporation, and this can be largely controlled by proper cultivation, at least sufficiently to secure a good growth of crops every year. It has been demonstrated by careful laboratory and field work by Professors King, Whitney, Hilgard, and others, that seven inches of rainfall is ample to grow a good crop of any kind, providing the water is all utilized. Measurements and records by the government weather bureau have shown that in the more westerly portions of the semi-arid belt the average rainfall is more than twice as much as is needed, while a little further east it is three and four times the necessary amount.

The usual difficulty, if such we may call it, is the fact that this rain does not always come just at the time the plants most need it. This is the reason crops have failed and the average investigator or observer of the existing conditions in this great belt has drawn the conclusion that there is not rain enough. We have lived in this belt of country twenty-eight years, and have experienced all the pros and cons, the ups and downs that the country is heir to. Sixteen years of this time has been spent entirely in the study of the soil, the movement of the moisture in the soil, and that all-important question of storing the rain waters. Our experience in these sixteen years has been quite varied, but each and every year some new and important fact has been brought out, all leading to the one conclusion, that the rainfall can be stored in the ground,

and its evaporation prevented by a proper manipulation of the soil, thus enabling us to secure, not only fair, but remarkably good crops any and every year.

The irrigator must consider this question of evaporation. As a matter of fact he has discovered that his great loss of water is from evaporation and he has studied to offset this. Placing water on the surface of the ground simply invites loss of the water at once. What must be done and what is done where irrigation is well understood is to place the water deep in the soil, and store it where it can be made use of at the right time and in the right way.

LOSS AT THE SURFACE.

The wonderful rapidity with which moisture rises by capillary attraction to the surface and is evaporated is not commonly understood. The most favorable condition for this rapid, upward movement of moisture is the natural condition found after irrigation or heavy rains, when the surface soil particles are dissolved and settled very closely together. Professor King has conducted some very extensive experiments in ascertaining the amount of moisture that would evaporate from a square foot of ground in twentv-four hours. This work was accomplished by placing a metallic tube one foot square in a tank of water so protected that there could be no evaporation or loss of water, except through this tube. The tube was five feet long, filled with soil from top to bottom, and submerged into the water four feet, so that the moisture to reach the surface to evaporate had to pass up one foot through the soil by capillary attraction. The rate of evaporation for ten consecutive days was a quart and a-half of water to the square foot. The tube was then lifted one foot higher, making it necessary for the moisture to rise two feet by capillary

attraction, when the loss was a little over one quart. It was then lifted to three and then to four feet, and when rising four feet by capillary attraction the loss was a little over a pint to the square foot. This shows clearly why our crops may suffer so quickly even after we have had considerable rain.

The experience of the writer in his own work in 1894, demonstrated clearly these two facts: First, that moisture will evaporate very quickly when soil is left in its natural condition; second, that a large per cent of moisture can be stored in the ground. In that year there was no rainfall after early May or during the month of June, and the average field was practically dry when the first rain came on July 7. At that time the fields were flooded by a rain of four and a-half inches which came down quickly. In the fields where we were conducting experiments we had previous to this time got the moisture down nearly three and a-half feet, and the surface was in the best of condition to absorb the fresh rain. In eight days the ordinary field was again practically dry. In such fields, owing to the great resistance of the dry soil, percolation was very slow, and the extreme heat which naturally followed quickly evaporated all the water which had fallen. But the field we had been carefully cultivating and had prepared for just such an emergency, was found to have a moist soil over two and a-half feet deeper than before, or down to a depth of six feet.

During the season of 1901, there were many demonstrations of the remarkable results following extra work done just at the proper time. A farmer near Fairmont cultivated once more after a heavy rain which came about the middle of July, after the farmers in that locality had "laid their corn by." This extra cultivation, which could

not have cost over thirty cents an acre, added fifteen bushels per acre to his yield of corn. James Armstrong, of Phelps county, double-disked his ground early in the spring, then cultivated his corn once more than his neighbors, at a total cost not exceeding sixty cents an acre, and got twenty bushels of corn per acre for his extra labor. This may seem like an exaggeration, but the comparison was made between this field and an adjoining field on his own farm not thus treated, as well as a comparison with the crops of his neighbors. Dozens of similar illustrations could be given of the immense value of this principle. If the work is done at the right time results are great.

GREATEST ELEMENT OF WASTE.

The careful tiller of the soil will, then, bear in mind at all times the fact that evaporation is the greatest element in the waste of water, that evaporation depends upon the condition of the soil surface and the atmosphere, that it is always immediately following a rain or an irrigation when the surface is compact and moist that evaporation is most rapid, that evaporation is comparitively slow from a broken and dry surface, and that by checking evaporation the farmer literally forces the water down into his natural store house or reservoir for water beneath the surface.

Cultivation of the surface of the soil is not alone to kill weeds or loosen the soil to admit the air—but it is for the purpose of stopping the waste of water through evaporation.

Evidence from all over the semi-arid west proves conclusively that if every farmer had fully understood the theory and principles of conserving the soil water by proper cultivation, there would have been no short crop of corn

in 1901 in that section of country. The excessive evaporation of the rain water all over the great plains country is the direct and sole cause of a greater loss to the farmers of that belt than any other one thing. Educate the farmers of the semi-arid belt to store, conserve and utilize the the rain water and we have paved the way for thousands more ideal farm homes and a higher state of prosperity than this belt ever experienced or the people anticipated. It is by and through knowledge of certain great fundamental principles of agriculture, and application of those principles to conditions which exist in this semi-arid section and no place else in our country, that this region is to come into its own, and be made, indeed, a veritable garden.

Evaporation of the rain water on the great plains country has made many a man hopeless and homeless. Prevention of the evaporation of the soil waters by proper cultivation means better crops, better homes, better people, happier children, and a better and more prosperous country.

CHAPTER XVII.

ADVANTAGES OF SEMI-ARID REGION.

Don't apologize for being a farmer of the semi-arid region. It is not advisable to be boastful beyond that which is easily demonstrated; but at least do not feel that in conducting the business of agriculture in a region where the rainfall is small you are defying nature. It is true that you may be defying the traditions of the past and doing violence to the old accepted theories on agriculture, but you need not concern yourself about these things.

Don't belittle your own state and your own farm by bewailing the fact that the rain does not fall as often there as it did on the farm where you spent your boyhood days. There were seemingly some advantages in having rainstorms so often and so great that the waste of great quantities of water was not seriously felt. It may be a nice thing to have more water than you know what to do with. But even this has its drawbacks. Perhaps it is better on the whole not to have so much water. Let us see.

The soil of the semi-arid region is generally of a loose and fine texture. There is nearly always present in the soil sufficient sand to prevent the soil becoming heavy. In large portions of the humid regions the soil is underlaid with clay in such a way that the storehouse for water is limited, or there is danger of the burning out of the soil. But this is seldom true in the semi-arid country.

In fact it is well known that by far the larger proportion of the soils of the semi-arid country is of almost unlimited depth and of uniform texture. This is an advantage.

DIFFERENCE IN THE RAINS.

In Farmer's Bulletin 266, published by the Department of Agriculture, Washington, D. C., we find also some discussion of the difference in the rains of the different sections. The Bulletin says:

"There is an important difference in character between the rains of the east and those of the west. The summer rains of the west, and especially of the plains country, consist largely of infrequent heavy showers. If the soil be open and deep, this rain sinks deeply into the ground. As previously mentioned the hot sun and drying winds of the semi-arid regions rapidly dry the topsoil and this forms a mulch, or covering, which retards evaporation. Light showers in a dry time do very little good. They wet the surface, and if the water extends to the moist soil below, water from below actually flows to the surface over the wet soil grains, and the water of the light shower, as well as some of that previously in the soil, is lost by evaporating into the air. In humid countries, where much of the precipitation consists of frequent light, slow falling rains, with much cloudy weather, the surface dries more slowly, giving less protection to the lower soil, so that much more water is lost from the soil as a whole than would be the case if the same quantity of water came in less frequent rains, provided, of course, the heavy rains all sink into the soil."

Bear in mind that it is practically always and ever true that the soil of the semi-arid country is in the best possible condition for soaking up all of the water rain which falls. If it is perfectly dry down to a great depth

it will not take up water as it should, but if only the surface is dry and beneath is found comparatively moist soil,—a condition which prevails where there is the right cultivation—then this soil will take up the moisture. The only problem then left is to save this moisture.

A DIFFERENCE IN THE SOILS.

In Farmers' Bulletin 257, of the Department of Agriculture, we find Professor Whitney relating an incident which nicely illustrates the difference between the semi-arid country and the humid regions. He said:

"Some years ago I saw some interesting soils in California. In some of the valleys they have soils that will produce a crop without any rainfall during the period of growth. At a point near Los Angeles, which I visited one September, they had a tobacco field which had been planted in April or May and had produced a crop which had been harvested. A sucker crop had been allowed to grow, and in September they were cutting the sucker crop, which had made a fair growth and was then in a very flourishing condition. The tobacco had had no rain since it was planted, but had been cultivated throughout the season as we do our crops in the east. With my hands I could scrape off the surface and get down to moist soil. The wells of that district showed the table water was forty feet below the surface. Such an occurrence appears a very remarkable fact to us here in the east, where we suffer if the rain does not come within two or three weeks.

"In trying to find out the reason for those peculiar conditions in some of the western soils, the fact presented itself that in those localities they have a very dry air, a very hot climate, and usually very strong winds that dry out the surface rapidly. They have about 18 or 20 inches of rain during the winter. After the rains stop in

April, if they immediately cultivate their surface soil and get it completely dried out, they thereby conserve the moisture, because any subsequent loss through evaporation will have to come from evaporation within the soil, and that is very slow, although slow evaporation does take place within a soil. If you fill a tumbler with moist soil and put it in the window in the sunshine, you will find that the heat of the window sill will make the temperature of the bottom of the soil higher than the temperatiure of the surface; you will then get evaporation from the bottom, and the bottom soil will dry out quicker than the top."

He did not explain, however, the direction which the vapor takes which he says is in the soil. Evaporation takes place only when there is some open avenue of escape for the water in the form of vapor. There is no evaporation from a hermetically sealed box.

It was no doubt a matter of great surprise to Prof. Whitney, as it has been to many others, to find crops grown in the semi-arid country without any rainfall during the growing season. They had a right to feel surprised when they scraped off the surface with their hands and found moist soil just beneath, and this where there had not been rainfall for months. And investigation would have shown exactly why the store house for water still had a supply on hand for the use of the growing plants. We have gone to many of our fields in Nebraska, Kansas and Colorado during similar periods, with doubting Thomases, who were equally as surprised as was Prof. Whitney, especially in 1894–5, and also 1901–2.

DRAWBACKS TO THE HUMID REGION.

The story of the California tobacco crop was told to a company of Maryland farmers, and continuing in response to questions, Prof. Whitney further explained:

"Conditions here are rather unfavorable for the con-

trol of moisture, because of our frequent rains. Strange as it may seem, while we suffer if we do not get rains, we should actually be better off, as they are in the arid regions of the west, if we did not have any rain during the growing season and had a means of providing water when we wanted it. There is no question that the arid conditions of agriculture with water for irrigation permit the most perfect system of cultivation. Such a system is much more efficient and crops are under much better control, if the conditions are handled intelligently, than they are here in the east. The trouble with us is that we cannot maintain this dry mulch. After a rain we plow or cultivate just as soon as we can and we get the surface moderately dry; then another rain comes on, and if we think we can afford it, we cultivate again; then still another rain comes, and we try again to get the surface dry. If you cultivate your soil after a rain just in the right time to catch the moisture in the soil, then if you have a drouth, cultivate by all means, keep cultivating and you will do much toward saving your crop. The Secretary of Agriculture has told of a very disastrous drouth while he was professor of agriculture in Iowa, when he saved his corn crop and got a normal yield by constant cultivation during the dry season, while his neighbors had almost a complete failure. As I told you, it all depends on the skill, the judgment, and the chance which led you to begin operations at the right time. If you knew what was coming you could save your crop during any ordinary period of drouth."

In view of the fact that it is no new discovery that conditions in the semi-arid regions are radically different from those in the more humid regions, and especially the character of the soil and its adaptability to the best pos-

sible cultivation, it is somewhat strange that so little has been done in making practical investigation of what should be done in the west to assure good farming operations.

IDEAL FARMING COUNTRY.

The vital truth is that the so-called semi-arid region is almost ideally adapted to best agriculture. The soil is of the right texture and capable of being handled to the best advantage. The soil has all the elements necessary for the highest degree of soil fertility. There is comparatively no loss by the washing away process. There is no carrying away of the surface bodily so that the subsoil must be transformed. There is practically no loss from drainage. The soil is easily made loose when that is wanted and easily compacted when that is desired. In short, no soil is seemingly more ideal for general farm operations.

Then the very fact that the atmosphere is dry, as a rule, is of great advantage, and yet so many had supposed it a detriment. The rain comes in the form of a heavy shower, and when it is over there is a dry atmosphere which quickly takes up the water from the surface, and with prompt action with the cultivator the formation of a soil mulch is therefore easily encouraged and of a nature that is very effective.

In short it is in the semi-arid region that the farmer can best secure that ideal soil condition that enables him to control the moisture which is needed for the growth of the plant.

Therefore we say again that no man engaged in farming in the semi-arid sections has any excuse for offering apologies. He has the best natural conditions for good farming. It only requires that he apply science and a reasonable amount of well directed labor, and his results are

more certain than with the farmer who lives in a region where there must be a good deal of guessing as to the soil, the rain, the sunshine, and the wind.

The semi-arid section having more sunshine and less rain makes it possible to not only prepare the soil into the most ideal seed and root bed, but it is also possible to keep the soil about the feeding roots constantly supplied with the necessary amount of both air and water. These coupled with heat and light cause nitrification as well as other chemical action through which almost unlimited plant elements are made available, and it is because of these facts and the further fact that such conditions can not be so readily and so continuously sustained in sections of greater rainfall and more cloudy weather, that the semi-arid sections have the advantage of greater average yields at less average cost, when work is scientifically done.

CHAPTER XVIII.

CULTIVATION OF THE SOIL.

The cultivation of the soil embraces, in a general way, about all of farming that relates to crop growing, but in a more restricted sense it relates merely to the treatment of the surface of the soil during the crop growing period.

It is absolutely necessary to good farming that the farmer have a clear understanding of the philosophy of soil cultivation. He must be able to consider why the surface is cultivated, how best to cultivate it, why different kinds of cultivation are necessary under different conditions, the implements to use, the time of cultivation and the frequency of cultivation. As already known to the reader who has conscientiously followed these pages, no general rule can be laid down for any portion of the work incident to agriculture. The processes nesessary to securing good crops cannot be put on a diagram that all may read. The most that can be done—and this ought always to be sufficient—is to thoroughly explain the general principles and make clear why each operation is performed and to tell just what effect may be expected from following any given line of work; then the farmer must apply this knowledge intelligently to the problems which come to him from day to day in actual experience in the fields.

So it is with cultivation, there can be no exact rule as to depth, or time, or frequency of cultivation. But

it can be made clear what a certain kind of cultivation will do under certain conditions. Then if the farmer knows what he wants he can adapt his work to his needs.

There has been a great deal of discussion as to the value of shallow and deep cultivation. Some persons have undertaken to make entirely too much of one or the other of these systems. The fault is that they have not always kept in mind that much depends on the character of the soil, and still more on the soil and atmospheric conditions which prevail at the time of the cultivation. It is not necessary to make an argument anywhere in the semi-arid region to convince the farmer that the old-style of cultivation of growing crops with the long pointed shovels is not proper especially in the light soils of the west. If he has had experience he knows that this method of cultivating his corn or potatoes is as likely to do harm as to do good. So he has turned to shallow cultivation as the natural alternative. But it is possible he has gone too far in that direction, an error easily made and quite common.

Shallow cultivation is not very well understood. There are times when it is just the right thing. But take it, for instance, in the drier portions of the west, where the atmosphere is free from moisture and the altitude is high so that vaporizing of the water comes at a low temperature, it is easy to cultivate too shallow. A little deeper will get better results, because it is necessary to have a deeper soil mulch to protect the moisture beneath.

SHALLOW VS. DEEP.

In the chapter touching on the growth of potatoes, there will be found two illustrations which will bear study in connection with this subject of shallow or deep culti-

vation. In cut No. 20 is shown a hill of potatoes which was grown by shallow cultivation. In this case, it is proper to add, the ground was first plowed eight inches deep, having been previously disked, the plow followed with a sub-surface packer, and the whole portion made thoroughly fine and firm. In securing this illustration, the lateral roots of many different hills were washed out. The main roots running from the stock were almost invariably found to have traveled in quite a uniform distance from the surface of moisture; the little branches running out from the main roots taking various directions, some lateral and some down.

The illustration quite perfectly shows all these important facts. Notice the two and a-half inch mulch, and the very fine, uniform condition of the balance of the furrow or plowed portion, where may be seen numerous roots. This represents a hill of potatoes taken from a field grown on our farm in Brown county, South Dakota, in 1894, when thirty-two acres of high, level prairie produced an average of one hundred and forty-two bushels to the acre, and this in a season when almost all the crops throughout the entire semi-arid belt were ruined by the extreme drouth.

In Cut No. 21, we give another illustration of potatoes grown under other conditions. This ground was treated practically the same as that shown in cut No. 20, but deep cultivation was applied, and less frequent. The field was cultivated three times, cutting fully four inches deep, which resulted in destroying nearly all the lateral roots, while the other field was cultivated eight times, cutting about two inches. The difference in the result of the two crops was attributed directly to the treatment of the ground after planting.

TIME OF CULTIVATION.

These illustrations show very plainly the difference in results between shallow and deep cultivation, but they also show another thing, and that is that the time of cultivation is a very important thing. Deep cultivation will certainly, under some conditions, facilitate the evaporation and waste of the water, and sometimes very shallow cultivation will have the same effect. The depth of the cultivation may well be varied to meet conditions as you find them.

If you would secure the greatest possible benefit from the labor given over to cultivation, you should first provide yourself with some fine-toothed cultivator, so that the soil may be all thoroughly fined, leaving the surface of the firm soil beneath as near level as possible. Then, great care should be taken to catch your ground in proper condition. It is true there is but little time after a rain that the ground is in the best possible condition. This is the time when the free water has all percolated below, and the soil to the depth which you wish to run your cultivator, is simply moist—neither very wet nor very dry. In this condition the little particles seem to readily separate, one from the other, then your stirred soil is composed of an innumerable number of little, minute lumps, forming a mulch that gives you the highest degree of protection. A mulch made when soil is in this condition will never blow.

If the soil be too dry it breaks into large lumps, which not unfrequently lie in such manner as to conduct the air through the large spaces between them down to the solid and firm soil beneath, causing much loss by evaporation. It is needless to mention the difficulty arising from cultivating soil that is too wet. When worked it

becomes what is known as "puddled," and then when dried it becomes hard as brick, and a heavy rain is required to even dissolve the lumps so that they may be pulverized afterwards.

SAVING THE MOISTURE.

There are two vital points in regard to the successful growing of crops in the western country. The first is the importance of getting all the water possible into the ground, and second, using every possible means to conserve or retain it there.

The importance, or value, of a little additional water is shown by the effect of snow drifts that may form on the field from any cause. The increased amount of moisture that seems to find its way into the ground when the snow melts invariably makes itself apparent in the growing crop as soon as a dry period begins to affect the crop in the least. At these points the crop always holds out longer, sometimes carrying the crop over to another good rain, which results in maturing an unusually large yield on these places, while the balance of the field will not yield to exceed one-half to one-fourth the amount. Thus a gain in yield of wheat of probably ten bushels to the acre is the result of perhaps not over one-half inch of additional water that had percolated into the ground. The enormous evaporation from our fields under favorable conditions is not in the least comprehended by the average farmer because he has no means of readily testing and proving.

EVAPORATION DANGER.

The danger to the farmer from evaporation cannot be overestimated. Therein lies the whole secret of good farming in the semi-arid region. If there was no water lost or wasted the deserts would blossom. Under the

heading of "Evaporation," we have given the results of some experiments by Professor F. H. King of Wisconsin showing the rapidity with which moisture will rise through the soil by what is known as capillary attraction, reach the surface and pass off in vapor into the atmosphere in a single day. Not until the farmer begins to grasp the vital importance of keeping even a little additional water in his soil can he be expected to use all diligence due in preventing this evaporation. This observation of the farmers throughout the semi-arid west, during the growing season of 1901, especially Kansas and Nebraska, ought to be amply convincing with reference to the value of stored water in the soil. There were frequent remarks during its prolonged and severe drouth of the mid-summer with reference to how the corn continued day after day and week after week, contending against this extreme heat without rain, without showing any apparent effect of drouth; but this was simply the direct result of the unusually heavy rains in early spring that percolated down into the soil, in many instances eighteen inches to two feet deeper than usual, and there acting as a reserve, continued to return by capillary attraction and feed the corn plants and other grain until it was exhausted. In this same chapter on evaporation we make mention of several instances where the early disking of the ground resulted in retaining a sufficient amount of additional water to carry a crop of corn through, increasing its yield in some instances as high as twenty bushels, which was not secured in adjoining fields, not disked, simply because the moisture was allowed to evaporate by leaving the surface hard and compact, as is always the condition after a heavy rain or snow.

SOIL CONDITIONS.

To be successful the farmer must grasp the full importance of doing all his work just at a time when the condition of the soil is best adapted. The idea that by plowing today we may get ten bushels of wheat to the acre, when if we plowed the ground four days later we would get fifteen bushels or vice versa seems rather ridiculous. While this statement and the figures used, may in most cases be a little strong, yet it is a fact that the average yield of a field is frequently increased or decreased quite a per cent by a few days variation in the time the work is done.

This is especially true with reference to cultivation. We have in mind a case near Fremont, Nebraska, where the phenomenal difference of fifteen to eighteen bushels per acre was made by cultivating a part of the field before a heavy rain of nearly five inches, and the balance of it after this rain. The reason of this remarkable difference was simply what we have been dwelling upon; the result of retaining a large per cent of moisture in the soil mulch by the cultivation after the rain, that was lost from the balance of the field by rapid evaporation. This occurred in July, and was the last cultivation preparatory to what is called laying the corn by. The rain was a very heavy one. The part of the field that was cultivated previous to the rain was left with the thick compacted crust made by the heavy fall of water, which resulted in dissolving the loosened soil and settling it very close, thus leaving the surface in the best possible condition for a rapid movement of moisture to the surface and evaporation. Under another head we have explained this more clearly. The portion not cultivated previous to the rain was gone over

as soon after the drain as conditions would permit, thus producing a perfect protection to the moisture below, and bringing about the remarkable result referred to.

While these cases cited seem like extreme instances, under similar circumstances you can look for similar results. When the reader begins to understand the direct effect of these conditions it will then be quite clear why a light crop was secured when a good crop might have been harvested.

TIME OF CULTIVATION.

The exact time for the cultivation of a field cannot be fixed by any arbitrary rules. Certain things can be stated, as for instance—

Too moist soil will settle, so that you have accomplished nothing by cultivation.

Too dry soil will break up into clods and the surface mulch will be imperfect.

Too wet soil will when cultivated, form a connection between the surface and the subsoil, so that moisture will be steadily carried to the surface.

Too dry soil will be left by cultivation so that the air goes down into it and carries away moisture.

But you should always cultivate immeditaely or as soon after a rain as the soil conditions become suitable. One of these conditions is that the soil does not adhere to the cultivator or tool used. Usually soil sufficiently dried so it will not stick will be such as will form the right kind of a mulch.

We do not mean by this that the soil should be absolutely dry on the surface. It is an error to wait for that time, for the moment the surface is apparently dry the crust begins to form. It is desirable to catch the ground just before this time when all the soil is simply moist,

and then there is a free and ready separation of all particles. In this condition the cultivator runs the easiest, the mulch made the finest and lies up loose and light.

The judgment of the farmer must be used with great care at this time. He must bear in mind just what he wants and try his best to get just such condition of his soil.

TIME FOR QUICK WORK.

There is no time in the year's round of duties when quick work even at the expense of many long days of labor is so much needed as at the height of the growing season, when advantage must he taken of every rainfall that favors us.

It must be borne in mind that every moment's delay after the soil reaches the proper condition causes you to lose water very fast. It is at the rate of a quart or over per square foot per day, providing it is clear sunny weather, and even more in case of heavy south winds. The more intense the heat the more frequent it is necessary to cultivate. A very good rule is to watch the condition of the firm soil just beneath the loose mulch or cultivated portion, and whenever the surface of this firm soil begins to show dryness it is high time to commence cultivating again.

We cannot impress this point more fully upon your mind than by referring you to that chapter which tells of the crusting of the orchard on the Pomeroy Model farm during the extreme dry period of 1901, and its effect upon the growth of the trees.

We had a simlar experience, but more clearly illustrated, in the cultivation of corn in Cheyenne county, northwest Kansas, in 1898. This demonstrates very clearly the great importance of being exceedingly cautious,

not to let any crust form under the mulch. We are of the opinion that many corn crops have been seriously injured by that condition, when with no more available moisture the crop would have come out all right had it not been for this crust.

KEEPING MULCH IN CONDITION.

There are many important reasons why great care should be taken to keep the mulch in perfect condition and prevent the loss as far as possible of any moisture by evaporation from the surface of the soil. The following paragraph taken from Professor King's book on "The Soil," conveys some important information along this line. We quote this because it bears the figures of his own practical observation at various depths in the soil, showing the effect not only of the surface soil getting too dry, but of light showers. He says:

"When the surface soil has its water contents reduced so the upper six to twelve inches are beginning to get dry the rate of capillary rise of water through it is decreased and it begins to assume the properties of a mulch. But when this condition has been reached if a rain increased the thickness of the water film on the soil grains without causing percolation, the capillary flow may be so certain that the surface foot draws upon the deeper soil moisture at a more rapid rate than before, causing a translocation of the lower soil moisture, the deeper soil becoming measurably drier soon after such a rain than it was before, while the surface foot is found to contain more water than has fallen upon it."

He cites experiments as proof of this important principle. Some of his experiments were very interesting and

instructive, showing that by wetting the surface capillary attraction was so increased as to show that moisture had moved up from the fourth and fifth foot below.

This emphasizes the fact that the tiller of the soil should understand these conditions that he may know just what to do to get the best possible yields.

CONCLUSIONS.

In closing this chapter we venture to repeat that we may emphasize some things taught.

Winter wheat will not winter kill in firmed, moist soil, while in loose soil it frequently thins out or kills out entirely.

A fine, firm root bed, with a loose surface or mulch, is a condition that will withstand the extreme dry periods longest without any injury to the plant.

Study well the question of thoroughly pulverizing and packing the lower portion of the plowing; a full understanding of its importance means many dollars, because it means a larger crop result.

Subsurface packing increases the moisture in the lower portion of the plowed ground and induces decomposition of the weeds, stubble, or manures that have been turned under, thereby adding humus, the all important ingredient for rapid plant growth, as well as enabling the plant to withstand drouth.

If you would get your soil to a condition of fineness and firmness, do all your work to that end when the soil is just slightly moist, for it then plows better, packs better, and cultivates better. Do not go to work on plowed ground that is dried to the bottom, whether plowed in good condition or not, and expect in any way to get the lower portion of the furrow in good condition. You may improve it. The closer you keep to the plow the better you can pack the under portion.

CHAPTER XIX.

BAYNYARD MANURES.

The use of barnyard manures in enriching the soil has become so universal that it seems almost strange that in large areas of the country but little use is made of it. In the eastern part of the United States, as well as in other countries, there is no need for argument to convince the farmers of the great value of barnyard manures. They have demonstrated it many times. They do not waste any.

In the western states, more especially in the semi-arid regions, farmers have come to have an entirely different view of the value of the barnyard manures. In the entire belt it is probable that at the present time a large proportion of the barnyard manures are burned or thrown away. This is all wrong. In no section of the country is the soil of such a character as to respond more quickly and effectively to the use of barnyard manures and in no place will the effect of such manures last longer, or be of such permanent improvement.

There is the best possible reason for this. The soil is light and naturally rich in the primary elements necessary to fertility. But it is also well adapted to holding moisture, and there is in fact, no great drainage of the water. There is much loss of the value of manures in regions where the rainfall is heavy, for the under drainage carries away the best part of it. In the semi-arid belt

there is none of this loss of fertility by drainage. The light rainfall is therefore a distinct advantage in the treatment of manures.

But there is difficulty in making the best possible application of manure. The atmosphere is dry and the soil may remain dry for a long period, so that the manure lies dormant on top of the soil. This is not conducive to nitrification or decomposition, and many farmers have failed to get good results. Then it is a fact that in the barnyard manure as it is gathered in this dry country there is much loose and coarse straw in an almost perfect state of preservation, not very well fitted for helping the soil. When the manure is plowed under, as it must be to get the best results, the soil is so loose and light that there is not sufficient weight to press the whole down, and make such a compact mass as best serves to make a good bed. The soil, with the fresh fertilizer mixed in, has retained an open and porous condition down to a considerable depth, which proves a detriment to the soil, with the natural result that the crop burns out and weeds gain the ascendency. The throwing of coarse manure on the top of the ground, leaving it in bunches, then plowing it under without special care in packing is of little value. In fact, this system of applying manure brings about a condition frequently much worse than if none had been applied. Especially is this true in the semi-arid region, where much greater care must be taken to get the manure perfectly mixed with the soil.

MANNER OF APPLYING

The best results have always been had in the semi-arid country by having the manure applied with a spreader, then using a sharp disk to double-disk the surface,

thus mixing the manure to a considerable extent with the top three inches of soil. We followed this by plowing six or seven inches deep, using a rod on the beam to turn everything under. This is then followed by the sub-surface packer which treatment results in firmly packing the soil and manures firmly at the bottom of the furrow. The reader should refer back to cuts No. 1, 2, 3, and 4, especially to note what we mean in this regard. The plowing under of manure that has not been well distributed is likely to leave the ground as in cut No. 1, which is evidently a condition that will not only waste the natural strength of the soil, but be wasteful to the manure that has been turned under. By use of the sub-surface packer the mixing is not only made perfect, but the manure is brought into actual contact wth the soil, when the proper processes bring about the development of the humus. Only slight moisture is necessary to develop the decomposition if the mixing is well done; much moisture will hardly suffice if the mixing and packing is not done.

The history of our experience in this matter well illustrates the common experience of others. In 1882 upon a South Dakota farm we gave a liberal coating of barnyard manure, plowed it under, and worked it down as best we could after the manner usually practiced in old Vermont. The rainfall during that season was quite liberal and timely. The piece, about five acres, was planted to corn and well cultivated, with such good results, that we decided to treat the manure question with the same care and economy as we were wont to do in the East. The same plan was followed out in 1883, with a total loss of all the crops which were planted on that ground. A small attempt was made again in 1884, with

the same poor results. For several years after this we followed the usual plan of the western farmer, of hauling it out and using any possible method to get rid of it.

REMARKABLE RESULTS

But the remarkable results each and every year from the field where the manure was applied in 1882, was too convincing of its value. For ten successive years this entire quarter section was put into wheat. Every year in the early stages of the growth of the wheat, the shape of this five-acre field, which was in one corner of the one hundred and sixty acres, was perceptible both in the color of the wheat and the development of the stools, and almost invariably at harvest time, the grain on this little piece would be from four to eight and ten inches higher than the balance of the field, and yielded invariably from fifty to one hundred and fifty per cent more.

With much study along these lines, and several experiments, to find out why such remarkable results were obtained from this field and why we could not succeed in later attempts, we were finally able to solve the problem fully. It is simply a question of mixing the manures into the soil as much as possible, and then firming the under portion of the furrow slice, thoroughly packing manure and soil, followed with careful cultivation, when the sam eresults may practically be attained any year that were secured in the seasons referred to, when we had the unusual amount of rain scattered along at proper periods at just the right time to produce decomposition.

The peculiarity of the formation of our soil is such that manures, when properly applied, very materially aid us in carrying our crops through the dry periods and preventing the serious effects of the drouth, for the simple reason that the humus, which is decomposed veg-

etable matter, very materially increases the water-holding capacity of our soil. The more humus we have in the soil, the greater is the number of particles, consequently the greater amount of surface to hold water. It also aids in the movement of moisture through the soil, and in the encouragement and development of root growth.

The existence of the humus in the soil we know to be absolutely necessary to successful growing of crops. It is where this humus abounds that we find the greatest development of nitrates in the soil, not alone because nitrates are carried into the soil with the fertilizer as a part of it, but because of the chemical action which takes place in the soil. A good deal is said about the carrying of nitrates into the soil, and in certain crops gathering the nitrogen from the air and storing it in the soil, but the fact is that the greater portion of the nitrates in the soil are prepared there by the chemical action which is always stimulated by barnyard manures.

PERMANENT EFFECTS.

There is one great advantage in the practical use of barnyard manures in the semi-arid belt. The effect is more lasting when the manure is properly applied than in the soils of the more humid regions. In these latter regions the greater rainfall has a tendency to wash out the humus below. This trouble of washing out is especially perceptible in the gravelly soils of New York and the New England states. There is another advantage of the semi-arid belt which will be appreciated when these facts are better understood by the masses, for our observations so far clearly show that manures are even more valuable here than in the east, not that our soil is not fertile, but the more humus we have in the soil the

more water will each square inch of soil hold, and consequently our soil is safer and less liable to suffer from drouth. There is but little expense attached to an experiment to ascertain the correctness of our assertions on this subject, and were you to make them, you would find more and surer profit from them than from government bonds. The sub-surface packer is a very valuable tool in securing immediate results from manure. Examination of the illustrations in this book will make this very clear, and the matter is not exaggerated in the least.

MANURE AND WATER.

Professor Goff in his book on principles of plant culture, says: "Much of the benefit of manuring undoubtedly comes from the increased capacity it gives the soils for holding and transmitting water."

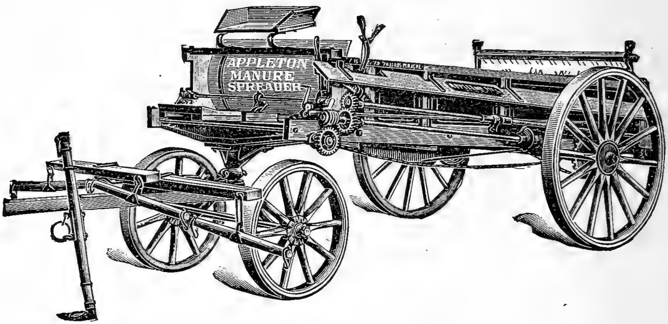
Professor King says in his book on soils; that in three years' experiments with barnyard manures he found "That for manure fallowed ground the surface foot contained eighteen and one-fourth times, or four thousand and eighty-seven gallons more water per acre than adjacent and similar but unmanured land did; while the second foot contained nine and one-fourth tons and the third six and one-third tons more water, making a total difference in favor of the manured ground of thirty-four and one-third tons or eighty-five thousand gallons."

We would advise, where it is possible, to plow manure uder in summer tilling fields, and in doing this it will be found that far less seed is needed for best results.

ECONOMY IN SEED.

The use of manure has such an important bearing on the proper preparation of the seed bed that its right use may go a long way toward saving in the use of seed

grain. The stalk sent up from an imperfect seed bed is of slow growth and scant of leaves. The stalk which runs upward from a perfect seed bed spreads out and probably branches, and the leaves are abundant and strong. If there is an abundance of humus in the soil there is stooling out of the stalk so that instead of one upright stem there are two or three or mayhap a dozen stems sent up to bear flowers and grain. It therefore follows that where manure has been used in a man-



A Modern Manure Spreader.

ner to develop in the soil the greatest amount of humus, so that plant food is more than sufficient for the needs of the plant, a very much smaller quantity of seed should be sown per acre than on soil less favorable to growth. If there is too much seed per acre the grain will stool too much and make so heavy a growth that it will stand up. Heavy stooling results in the weak straw carrying down the grain, and in this condition the grain will not fiill and it often happens it cannot be harvested.

The right use of manure therefore, partially compen-

sates itself in the economy in use of seed. In no one thing are mistakes more common than this of the right amount of grain for the fields in the semi-arid belt.

THE MANURE SPREADER.

While the manure spreader is a very valuable farm implement from a time saving point, yet its great value lies in the fact that the manure is thoroughly torn into small pieces and very evenly distributed over the surface of the field. It will pay for itself in a short time providing the farmer will use great care in mixing the manure with the soil, plowing it under at a fair depth and then firming the soil with a sub-surface packer. It only takes a little manure per acre and a little intelligent mixing and preparing of the soil to easily double the present average yield.

Barnyard manure must be handled with good tools and be treated as something distinctly valuable. To throw it upon the land and trust to luck, is worse than time wasted.

CHAPTER XX.

CORN GROWING.

Corn is a crop which requires a season a little longer than small grain and the crop does not thrive best where the nights are cool, so that the northern limit of the corn belt is easily reached. But with care corn may be grown far north in a satisfactory manner and is a good crop in a large part of the semi-arid region. The care referred to relates to the preparation of the seed bed, the previous fitting of the soil, the manner of planting, the time and manner of cultivation. No crop is more responsive to good treatment than corn. No crop suffers more from carelessness or ignorance on the part of the farmer.

The first thing a farmer must consider is the preparation of the soil. Corn is a crop which demands cultivation during the growing season, put it also demands a preparation quite equal to that of wheat or other grains. Among the hills of New York and New England the farmers give a great deal of care to the preparation of the soil for the corn crop, for the farmers have learned by experience that it is poor economy to put good seed corn into badly prepared ground. It is on the corn fields that they most generally use barnyard manure, and it is not infrequent that they treat the corn ground to from $2 to $4 worth of fertilizing per acre, there being many places where this seems to be necessary every year if good crops are to be had.

Professor Bailey, of Cornell university, has well said

that no after cultivation can make amends for a poor job of preparation of the soil. This applies with much more force to the semi-arid belt than it does to the eastern sections of the country.

In Illinois and other states of the Mississippi valley the soil is more fertile and rain usually ample so that no fertilizers are required and when the rains are ample and timely two or three ordinary cultivations during the growing period produce a good crop of corn, But even there they are beginning to leased the value of conserving the water by more frequent and timely cultivation, because of dry periods that are likely to come at any time. They are also learning that the breaking up of the crust which has formed on the surface after a rain is valuable because it admits the air to the soil and makes the corn grow better. But with us in the semi-arid belt, more attention must be given to the preparation of the ground. We cannot depend upon heavy rains to aid us in dissolving and settling our soil, consequently we must give close attention to every part of the work.

The first thing in order in the spring in the preparation of the soil for corn, is the early disking which should be a double disking in order to thoroughly pulverize the surface, bearing in mind that every act should be with a view to storing and providing the greatest possible amount of water in the soil. Early disking covers the two important points referred to, that of preventing evaporation and opening up the surface to receive the later rains. This done we simply wait for the proper time for further preparation and planting, always being in readiness, however, to loosen up the surface at any time should we get a rain of any magnitude.

USE OF THE LISTER.

There is some diversity of opinion as to what is the best way to plant corn. We prefer the use of the lister over that of the check rower, especially in the higher altitude or in the northern states where the nights are cooler, which results in heavier suckering or stooling. The additional shoots are very detrimental to the corn crops, especially should we have a dry season. In the humid sections, and on the rolling land, we still prefer the check rower.

There is one distinct advantage in the lister which is worth a great deal to the farmer in some cases. When there are symptoms of suckering, or the conditions are such as to cause this, we may, by filling the furrow and covering up the young shoots destroy them completely and with ease. The higher the altitude and the drier the atmosphere, the deeper is it necessary to cultivate in order to produce a deeper mulch to prevent evaporation. In using the lister on ground where the moisture has been carefully preserved by disking and harrowing in the early spring it is quite important to follow the lister with some tool to thoroughly pulverize the moist soil that is thrown up as such soil soon assumes a dry and a very hard condition which is afterwards difficult to manage. There ought always to be enough time so that the surface of the soil can be cared for after planting and before it is necessary to begin the corn cultivation. The best tool for treating the soil surface at this period is the weeder. The long and flexible teeth lap down on the side of the furrow or ridge as thrown up between the rows and quite completely pulverize the large clods that are thrown up by the lister, leaving a perfect circle with a nice fine mulch over the entire surface. This puts

your ground in magnificent shape, especially in the sand soils of the semi-arid belt, so that you can continue the use of the weeder by going lengthwise of the ridges and completely destroy the weeds before they assume any size, keeping your mulch in perfect condition to prevent evaporation, going over the ground after each rain, as in the cultivation of other crops, watching the condition very closely in order that you may catch the ground just when slightly moist before the crust has begun to form. This does away with the weed cutting idea.

THE WEED PROBLEM.

The importance of getting ahead of the weeds and keeping them down cannot be overstated. It is almost impossible to select words from the English language with sufficient force to impress upon the average farmer the serious detriment to crops of even the small weeds. To get a good corn crop the weeds must be kept out. And it is far easier to keep the weeds from growing than it is to kill them after they have become strong. An illustration of what can be done in the semi-arid belt will be given.

On the Kilpatrick ranch, in Chase county, Nebraska, in 1903, two hundred and seventy acres of listed corn were handled in this manner. The weeder used was the combination weeder and harrow made in sections the same as the common steel harrow. This is an implement that will be soon on the market generally, and its use will be common. We used enough sections to cover six rows of the corn, and the entire field was gone over four times before any other cultivator was used, and the corn was then about eight to ten inches high. The suckers or stools were from two to five inches long. A two-row riding cultivator with two wide shovels on each

side was then used throwing the soil from the ridge over the suckers to cover them up and practically leveling the ridges down. A few days later it was with considerable difficulty that a sucker could be found, in fact, with care and catching the corn at proper height the suckrs can all be destroyed. The cultivator was followed with the weeder, which practically leveled the surface. The corn was now ten to fifteen inches high and scarcely a broken stalk could be found, owing to the fact of the flexibleness of the teeth and that the drag or weeder bars were seven inches high. The field was gone over five times with a weeder, that took in six rows; and this cost less than to have gone over once with a one-row cultivator and twice with a two-row cultivator. This made the total cost of eight cultivations equivalent to less than two and a-half times over by the old plan. The corn made over forty bushels to the acre. Many other similar illustrations of what can be done might be cited in the country just east of the Colorado line.

In growing listed corn we do not believe in very deep listing, but in thorough cultivation from early spring until the crop is put in, then consider fully that ample moisture and air must be in the soil and that weeds growing in a corn field live on your best corn.

We will never get the high limit in yield by listing corn into the unplowed land. The plowing of the land to a good depth in the autumn, following with the subpacker well weighted, then early spring culture and listing shallower, would bring much better results. In short, a three-row lister is now being perfected for fields thus fitted and a three row cultivator will also be ready

CHECK ROW PLANTING.

Early plowing is absolutely necessary in making use

of the check row planter. The earlier the ground is plowed the better, provided it is not plowed when too wet. But there must also be the disking process in preparation for the plowing, for the problem of evaporation also comes in very early in the year, and the disking puts the surface in condition to prevent this and to encourage the percolation of the later rains into the soil. The use of the disk is advisable since you can get onto the ground with the disk and do good work when it would be too wet to plow at a proper depth. And you can cover the field quicker with a broad gauged disk than with the plow. It also enables you to get your soil in much better physical condition than would be possible if the ground were allowed to dry out. The plowing should be followed up soon after, but remember this point —if you have been particularly persistent in preventing this evaporation by the disking your ground is in perfect condition to plow, even though you have considerable dry weather later in the spring. The soil will roll up in a moist condition, and is susceptible to the best results with the packer or any other tool. Follow the plow closely with the packer, at least every noon and night.

There are few places where the subsurface packer turns the profit it will in following the plow in preparing a field for corn. An experiment on the Burlington farm in Phelps county, Nebraska, in 1904, where a strip of land in a field being prepared for corn was left without packing, the following facts were observed: Germination was four or five days slower; the stand of corn much less uniform and the final yield per acre fully fifteen bushels less.

WATCHING THE MOISTURE.

Fall plowing is preferable at all times where the crops

can be handled so as to permit. But never plow when the soil is dry. It is better to wait until spring and then disk early as indicated above. It is impossible to put too much stress on this point, and some farmers seem never willing to accept the reports of others as to experience. Nothing short of paying the price of forty bushels or more per acre of shortage will convert the average man.

A most beautiful illustration of the difference in crop yield from moist and dry soil was developed near Verdon, Nebraska, in 1906. The farmer had in the early spring disked a part of a 1905 corn field to raise a new variety of oats, but failing to get the seed, the entire field was again put to corn. All southeastern Nebraska was very dry that spring. By the time the man was ready to plow for corn, he found the undisked portion of his corn field quite dry. The field was plowed crosswise of the disked portion. He was very much surprised to find the disked portion moist when he began plowing, but very much more surprised to get 67 bushels of corn per acre from the disked portion and only 41 bushels per acre from the undisked. The whole field was treated just the same after planting.

After your ground is turned over, and the necessary work done to pulverize the surface, watch closely the condition. Whenever any rain comes, even though it only wets through the mulch or loose soil on top, it is necessary to immediately stir it to dry it out.

The importance of quick work after the surface has been moistened, even by a slight rain, cannot be too strongly urged. In the use of the check row planter the difference in the time of germination, the rapidity of the young plant in ground prepared as outlined under the

head of plowing and sub-packing, as compared with corn put into the ground in the ordinary manner, is interesting. The growth of roots as shown under the topic of root development is also an interesting matter.

AMOUNT OF SEED.

Here is another thing about which there is a great diversity of opinion even among the experienced corn growers of the west. Perhaps experiences have been different. Condition of soil and climate have something to do with it.

But do not put in too much seed. Better not have all that you think ought to be in the field. There are unquestionably many cases where light crops are due to the presence of too much seed in the ground. Half as many stalks growing would have done better as producers, and the crop would have been two or three times as great.

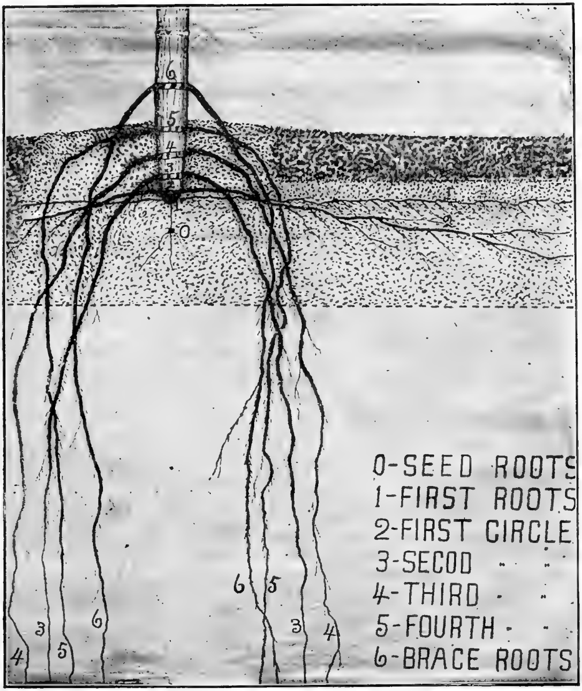
The remark is frequently heard: "If you don't put in the seed you can't get the crop," indicating the crop was gauged by the quantity of seed. This is another mistake and is beginning to be more generally understood. The strongest evidence along this line is found in some experimental work which we conducted in 1897, where eight ears of corn were raised from one single kernel. seven of these were well developed ears, the eighth having corn about half the length of the cob, both the upper and lower ends of the cob being bare of corn. It may not be generally known, but it is a fact, that a stalk of corn starts from five to ten ears, and some or all of them will usually be abandoned by the stalk before the ear is in fact developed. Now the development of these ears depends entirely upon the physical condition of the soil and an ample supply of avail-

able soil moisture, air and plant food at all times. It is true there are instances, or conditions that might exist by which more corn might possibly be got from two, three or four stalks in a hill than one. These would be rare cases, and where by extreme heat the demands upon the supply of moisture and plant food might suddenly destroy the vitality, or life of all the ears that were started on the corn, except the top one. Then a sudden and liberal rain immediately replenishing the soil about the roots with the necessary moisture which would immediately increase the available supply of plant food and push to completion the single ears left on each stalk, when we would have two, three, or four ears to the hill as against one ear if we had but one stalk. Then again should the dry period continue longer without any rain we might lose all the ears, because the demand for moisture to supply the growth and develepment of two, three, or four stalks would be just that much greater than for one stalk, consequently the one stalk could endure the drouth longer without suffering, and probably reach the next rain when ample moisture would mature one or two good ears as against none at all with a larger number of stalks.

ROOT DEVELOPMENT.

The number of ears therefore, does not depend entirely on the number of stalks growing. It is substantially true that it is possible to secure as many ears from a crop with one kernel in a hill as from three kernels in a hill. In the semi-arid region it is much more probable the one-kernel crop will beat the three-kernel crop. However, where there has been storage of the moisture and the soil is well prepared we prefer two kernels in the hill and believe that we can get best results from this amount of seed.

In the accompanying illustration we show a single stalk of corn and the general direction and development of roots. This illustration was made from several careful investigations of the location and development of



Development of Corn Roots.

corn roots. In the right hand corner you will note the figures 0 to 6, each indicating the circle of roots, 0 indicating the first development, or from the germination of the kernel of corn, while No. 1 indicates the second growth

of roots, which almost invariably is found to run very close to the surface of moisture. The depth of the early cultivation of the corn, providing we have no immediate subsequent rains to moisten the cultivated portion, largely regulates the location of these roots, therefore it is well to go slightly deeper the first time. No. 2 indicates the third line of roots, which is almost invariably found, although starting from the stalk a little higher, to make its way to a lower point beneath the line from which roots No. 1 seem to feed. These roots although only shown in the illustration as being single roots running to the right and left as we look at the stalk of corn, yet there is an entire circle around the stalk running in every direction, providing the condition of the ground is such as to encourage them. Here one can readily see the importance of cultivating as deep the first time as in any previous cultivation, for these roots find their way out through the soil in the early stages of the growth of the plant. Roots No. 3, which is the second circle of roots, are what are properly known as brace roots. These roots, like the subsequent roots 4, 5, and 6, find their course very largely straight down into the soil. They, however, convey but a small per cent of moisture and plant food to the corn. This being almost entirely the work of the roots shown by 1 and 2. Here in this illustration can readily be seen the serious results from deeper subsequent cultivation, which might result in cutting off many roots. We can also see the importance of all work as outlined under the various headings referring to the preparation and care of the soil being carefully carried out.

RESULT OF GOOD CULTIVATION.

Here in this illustration is represented corn put ni

with the check row planter, the ground plowed fully seven inches deep, thoroughly pulverized and made firm. Now, supposing we have carried out the necessary work to have stored and conserved moisture to considerable depth, five or six feet, with our plowed ground thoroughly pulverized and made firm, we have the best pos-

Cornfield by Campbell System, 84 bushels per acre, Lisbon, N. D.

sible condition, as stated under the head of sub-surface packing, for the three all important conditions which we so frequently mention. That of holding the greatest possible amount of moisture in the soil, a condition to

promote the most rapid movement of moisture by capillary attraction from the sub-soil up into this finely pulverized portion. Also a condition most favorable to the development of roots and root hairs or feeders. Careful investigation of fields thus prepared after the stalks of corn have reached a height of three or four feet will show almost a perfect network of these little roots and feeders throughout the entire field. Scarcely a spot half an inch square can be found that is not permeated by many of these little hair roots seeking the moisture and plant food therefrom.

With our moisture in ample quantities below, as stated, and this perfect condition of soil and development of roots, the growth and development of a magnificent crop of corn now depends entirely upon the time, manner, and kind of cultivation. It is not absolutely necessary that the farmer should have a specially fine toothed cultivator. The eagle claw cultivator, that carries four shovels on each side of the row, is probably the best in general use. Again we must repeat the importance of watching closely the condition of the soil, that as much of the work as possible may be done at the time, immediately after a rain when the soil is simply moist and the soil grains seem to most readily separate one from the other, as in this condition the most perfect and uniformly fine mulch may be produced.

In connection with the preparation of the soil the farmer should never overlook the great value of summer tilling of the soil with a view to bettering, not for one season alone, but for many seasons, the general condition of his soil. The marvelous results reported from fields summer tilled in preparation for a crop of wheat may be expected in proportion from corn crops, and it is

worthy of careful experiment by every farmer in a test field. Few can comprehend or believe the greatly increased yield possible from summer tilled fields over ordinary fitting of the soil for crops until they have seen the marked results from a test.

BROAD GAUGED CULTIVATORS.

Persons who have learned well that time is an important element in cultivation, also realize that appropriate implements are necessary. Cultivators must be built on the broad gauged plan if farmers are to be successful in cultivating the ground when it is in just the right condition, a condition that does not long exist after a rain, and manufacturers are trying to supply this demand. A two or three-row machine is very important, that we may cultivate two or three times as much ground in the same length of time, and when the farmers come to understand the importance of rapid work and the demand is made, such tools will be produced, for Yankee ingenuity is prevalent in all our big manufacturing establishments.

The fact is that we have not had in the great semi-arid belt any season when it was not possible to keep the soil in such condition as would be suitable for good crops with the proper machinery. Such conditions as indicated here have been held about the roots of the corn by proper cultivation. With the loose mulch on top, to a depth of two and a-half to three inches, produced when the conditions are just right after a rain, and stirred just often enough during the long dry periods, we can practically prevent any loss whatever by evaporation from the surface. This accomplished, the perfect physical condition of our soil and complete development of roots will take the moisture from below sufficiently fast to pre-

vent practically any damage from extreme drouth, and produce a most magnificent crop of corn.

THE CORN AREA.

The corn area is greater than has been advertised Corn is not limited to a narrow belt running through the country. Good corn has been grown in western Florida where it was once supposed no corn could be grown. Good corn is being grown every year north of the Canada line. Good corn is being grown on farms far up the mountain slopes of the west. This does not fit in well with what the old books and newspapers have been telling us. What is the reason?

It is not that we have got new varieties of corn from Siberia or Patagonia, nor is it merely that we have been acclimating corn for these out-of-the-way regions, though a great deal does depend on the selection of the seed for corn.

It used to be said everywhere, and it was believed by everybody, that corn could not be grown where cool nights prevail. Our best authorities also declared solemnly only a few years ago, that corn could not be grown north of Iowa, nor at an altitude of 2000 feet or over. New we find large yields of corn have been grown at various places in North Dakota and elsewhere at an elevation of over 6000 feet. At Walsenberg, Colorado, at an altitude of 6800 feet, one variety of corn, an early dent variety, has been grown with great success for seven consecutive years. The fifth, sixth and seventh years, the yield was over 40 bushels per acre. The acclimation of this corn has much to do with the success achieved, but the greater part of the success is due to the fact of a better understanding of the soil and how to till it.

Corn is the one staple crop on thousands of farms.

It is a decidedly profitable crop where it can be used rightly, as for instance, where hogs and cattle are grown,

Raised by Campbell method. Raised by common method.

Pomeroy Farm corn grown in the excessively hot weather of 1901; Campbell system vs. adjoining farm.

and it can be used on the farm for feeding. But of course its cost is much less per bushel where 60 to 100 bushels are grown than where 20 to 33 pushels are grown. To raise this limit means dollars to the farmer, and it is therefore worth a great deal to him to make a study of the problem.

SEED CORN TESTING.

It never pays to plant any kind of seed that is poor. In one respect the farmers of the semi-arid region are favored, because the climate is such as to preserve seed better than in some other places; but in another respect they are at a disadvantage, for the shortness of the season may prevent them from gathering mature seed. The only safe thing to do is to gather the corn for seed carefully before the frost has got a chance to injure the kernels, and put the corn in a place where it will dry out slowly and surely and remain dry all winter. Selection of seed corn from the field before the regular picking of corn is undertaken can do no possible harm, and it may be the means of saving an entire crop in after years.

Then before planting, no matter how careful the farmer has been, it is to his advantage to make a thorough test of the corn he intends to plant. This may be done in a variety of ways that will suggest themselves to every farmer. The testing should be done early enough so that if the farmer finds that 10 or 20 per cent of his seed will not grow, or even if 5 or 2 per cent produces weak stalks, he can supply himself with seed in some way.

INVESTIGATE AND KNOW.

The facts we have given here in this chapter on corn ought to suggest to every farmer in the semi-arid region, especially every one who has accepted the old dictum that corn cannot be grown here, that he should experi-

ment and know for himself whether corn can be made a good crop on his land. A small field for experimental purposes is easily handled. If corn can be grown, and yields of from 40 to 75 bushels secured, it is folly to be trying for yields of from 10 to 25, and equally bad to be devoting the land to some other crop exclusively. The farmer who wishes to intelligently convince himself what is best for his particular section would do well to lay off three or four small fields and try corn cultivation under somewhat different conditions, then act accordingly.

TO REMEMBER.

Here are some things to remember in connection with the growing of corn in the semi-arid regions:

Plenty of water in the soil means plenty of corn.

No after cultivation can make amends for a poor job of preparing the soil for the crop. Do not forget this fact.

The deeper you can get water stored down in the ground before planting time the surer you are to get a big crop.

Don't get too much taken up with the idea of shallow cultivation. The best condition is with from two and a-half to three inches of fine loose soil.

Be ready in the spring before the ground is ready, then at first chance get into the field with a disk and go over the ground intended for corn. Nothing can pay better than this, no matter whether the ground was plowed the previous fall or not.

Cultivate your growing corn once after the last rain, even though you may think you do not need the water for this crop. You may need it for next year and the time to save it is just after it has gone into the ground,

Never permit a crust to form under the mulch. It is

as bad there as it would be on the surface, and it will form there unless you watch closely during long periods of heat and drouth.

There is no work done, cost considered, that seems to go further toward increasing the yield of corn than that of early double disking where the land is not fall plowed.

Do not permit the weeds to grow. Every weed means less corn. They are silent thieves that take away all that you have saved up for your crops.

Be sure of your seed.

CHAPTER XXI.

WHEAT.

Wheat is one of the great staples of the world; bread made from wheat flour is the most common wholesome food for all classes of people. It is produced over a very large portion of the world, and yet an over-production seems impossible except that it may be from a local condition at a time following a shortage in a country that may export large quantities, a sudden shortage by drouth would turn other purchasing countries to other sources, then when the country reached its normal production again it might find difficulty in getting the same trade back; but in a country like the United States with its city population so rapidly growing, no man need fear the over-production of wheat if it is kept steadily on the increase.

The main object of this chapter is to show how fluctuation may be prevented and a steady advance in yield may be sustained. One thing is certain, cheap land does not mean cheap wheat; cheap wheat is produced by increasing the yield per acre without materially increasing the labor and total cost of production. It is to this end we have spent almost a life time, and have reached the point where to us it seems ridiculous for a farmer to own a portion of land and spend his time in directing the work and only get 10 to 15 bushels per acre.

There are no good wheat lands in this United States that cannot be made to yield three and four times this

amount, and especially is this true in the great semi-arid section, and that simply by and through a better understanding of the soils and their cultivation.

As there are two distinct kinds of wheat, spring and winter, and the time of seeding so widely different, we must of necessity treat them under the two headings.

SPRING WHEAT.

Spring wheat in the northern sections and on up into Canada, has become a very important crop. In preparing ground for this crop little attention has been given in the past to the all important question of storing and conserving the rain water. It has been simply a question of plowing at any time when the farmer was ready to plow, the seeding and harrowing likewise, without reference to the condition of the soil, or the storage of water.

From 1902 to 1906 there has been a growing tendency to early fall plowing. This has been encouraged largely because of the possible rain of sufficient magnitude that might to some degree dissolve the plowed soil and settle it more compactly in the bottom of the furrow. The tendency during the same years has been not to plow more than four or five inches. This is because there has not been any general knowledge of soil physics and scientific soil culture. Therefore the attempt to overcome one evil by committing another in the more arid portions of the wheat belt in the northwest and all similar sections. The application of summer culture methods as outlined in this volume would greatly improve wheat growing, land values and prosperity generally,

As previously stated during the past seven years of our very marked success with summer culture its principles unfortunately have been confounded with summer fallow. This fact has very materially retarded its general

endorsement for the reason that almost any farmer knows that to summer fallow as commonly practiced is a waste of time and money. In the semi-arid belt it scarcely improves the physical condition of the soil and does not materially increase the available fertility. While we have thoroughly discussed this question under another heading referring especially to that of "Summer Culture," yet its work is of such great importance, and the additional expense so little compared to results, that we cannot resist a repetition in part. If the work is properly done the returns are large. Begin first in the early spring, just as soon as the frost is out of the ground, and the soil sufficiently dry to permit of disking without the soil adhering to the disk, lapping half, so as to thoroughly pulverize the surface; thus putting your ground in condition to prevent evaporation, as well as to admit of the rapid percolation of the early rains and you will be surprised at results. Keep the surface harrowed or loosened by the use of some tool to the depth of at least two inches, plowing in June or July, the time when the other work is least pressing, to a depth of six or seven inches, following the plow closely with the sub-surface packer and let the packer be followed closely with the harrow, keeping in mind that all important point of working the soil when it is in the best condition to most thoroughly pulverize, continuing this surface cultivation after the plowing through the entire season. In this kind of work in the northwest, as well as in any portion of the semi-arid belt, it is very important to do this surface cultivating, whether it be with the common harrow or spring tooth or disk, at a time when the soil is in the best possible condition; that is, simply moist, not dry or wet. Then you have a fine, even soil mulch composed of minute lumps, a condition you cannot get if the soil is dry

or wet. It is when soil is in this condition that the particles seem most readily to separate, not simply into dust but these minute lumps made from slightly moist soil when dry will never blow.

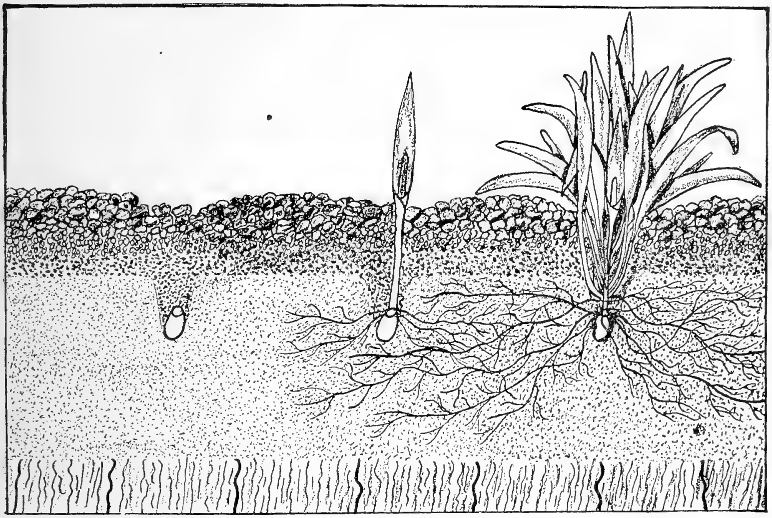
Having had fifteen years experience in the northwest we are well aware of this blowing difficulty on the lighter soils, which can be entirely prevented by care with reference to the conditions of the soil as above stated. It is very desirable in following this plan to **keep** the **weeds entirely clean from the field.** Don't for a moment encourage the idea that weeds are valuable to turn under, for there is so little value to them that it is not worthy of consideration, but the water drawn out of the soil by these weeds while growing is far more valuable to the coming crop. Watch it carefully. In the spring time try to catch this ground as early as possible with the harrow, and put in your seed not to exceed one-half bushel to the acre. This quantity is ample.

As noted in the following section of this chapter the largest yields we have ever got, 62 bushels per acre of winter wheat on summer tilled land, was grown from 20 pounds of seed, one-third of a bushel. Notice cut No. 16, which represents the ideal condition of the soil. The lower portion of the furrow or plowed portion has been made fine and firm, first by plowing when the soil was in perfect condition to plow, as explained under heading of "Plowing," then fined and firmed by following with the subsurface packer, and the surface kept loose by cultivation.

THE DRILL

The drill used is what we term the closed heel shoe drill, with shoes six or seven inches apart. It is our aim to let the shoe run from one-half to one inch into the firm moist soil beneath the mulch as shown in the illustration at the

left. The seed is deposited in the bottom of a "V" shaped crevice, as there it rests in a bed of moist soil. Germination is rapid because of the ideal condition, air in proper quantities reaches it through the fine but loose soil above, and moisture is plenty because the kernel is closely sur-



Cut No. 16. Wheat in Three Stages of Growth; Kernel, Single Stalk and Stooled Out.

rounded bv fine, firm soil carrying all the capillary water it can hold, which is quickly given off to the kernel as soon as it comes in contact with the many moist particles.

In the center we have the blade about three inches above the surface. This stage of growth we have almost invariably noted on the morning of the fourth day after the seed is deposited, when this ideal soil condition is attained. Such rapid growth of the stem is due only to the

fact that a perfect root system is immedaitely established, as shown in illustration, because of the perfect physical condition of the soil and the large amount of available fertility that has been developed by the summer tillage. Remember the physical condition of the soil above represented is very easily attained in all semi-arid sections.

At the end of the cut we have the same kernel a little later. Note the liberal stooling. The one lone stalk has developed dozens more, and why? Because of the enormous root system that has developed, and in every conceivable direction from the bottom of the stem these little rootlets have penetrated the soil, from these little rootlets thousands of little hair roots or feeders are drinking in the moisture laden with plant elements, sending it to the main stalk; but small as it is it cannot begin to utilize all that this little army of food gatherers bring in; the result is another stalk and another until enough have pushed their leaves into the sunlight to take care of all that is gathered in and provided by the roots.

Now take notice that we are approaching a possible big crop of wheat, for it is probable we have an average of ten, fifteen, or twenty heads started to every kernel we planted. If we can finish and mature a good head on each stalk what can we look for in yield. Two things, both of which are largely within the power of man to control, must be previously provided for, water and available fertility. We may have plenty of moisture and yet not the fertility; moisture can be stored as shown under the head of percolation. Fertility in case of a summer tilled field as shown above was developed during the heated portion of the season when the soil was fine and firm, with a loose mulch over the surface holding the moisture at the top of the firm soil into which the air readily per-

meated after passing through the loose mulch on the surface. With the air and the moisture, through the medium of heat and light, chemical action takes place and the available fertility is the result; and so long as ample moisture can be supplied from the storage below by that wonderful phenomenon, capillary attraction, which never fails to do its part, all necessary plant elements or fertility are ever available to complete the big crop.

Remember there are three requisites for the big and sure results, a perfect physical condition of the soil, fertility made available, and ample moisture stored below.

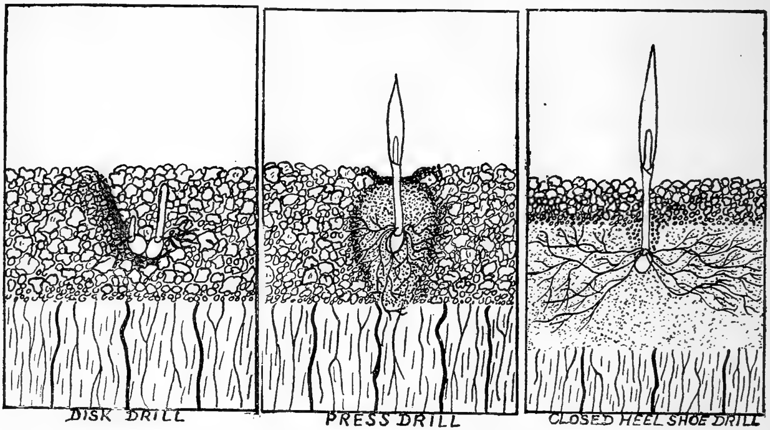
KIND OF GRAIN DRILL.

That the drill is by all means preferable in planting all small grain, there is practically no denial. Especially is it true in the more arid sections, but there are many kinds of drills of the more common makes, as there are three especially different methods of depositing the grain.

In cut No. 17 we show practically the condition of the soil after one of each. There is no question but what many will criticise some of our ideas, but we do not draw our conclusions from theory or from short and hasty consideration, nor without careful comparative tests. The disk drill is quite popular, its draft is light, but it does not leave the grain in anything like an ideal condition; for the soil is lifted and left loose over and around the kernel.

Next to this is the press drill. Note the difference in germination of the grain of the two. By packing the soil onto the kernel with the press wheel you notice more perfect rooting and the growth is considerably in advance of the grain put in with the disk drill. The press drill has its objections, especially is this true where the seed is deposited in soil that has not been sub-packed, as was the case from which we secured our illustration.

In seasons of normal rainfall with the usual dry period in May or June, the condition as shown would bring a small yield of wheat. The action of a press wheel is somewhat coarse and loose, or we might say the soil as it is found by ordinary fitting is not what most farmers imagine. The shape of the packed portion is much the shape of an egg little end down, as shown in the cut. The result is a rapid



Cut No. 17. Effect of Seeding with Three Kinds of Drills.

early growth of roots and a liberal stooling; the roots and rootlets, however, are mainly confined within the finer and more packed portion as shown in cut. This fact we ascertained by cutting a deep trench across two rows thus planted and with a fine stream from the nozzle of a small hand-pump, such as is usually used to wash buggies with, we brought out the conditions shown. Now the trouble usually is soon apparent when a dry period comes on after the early rank growth when all the plants and all the stools are obliged to depend mainly on this narrow packed strip,

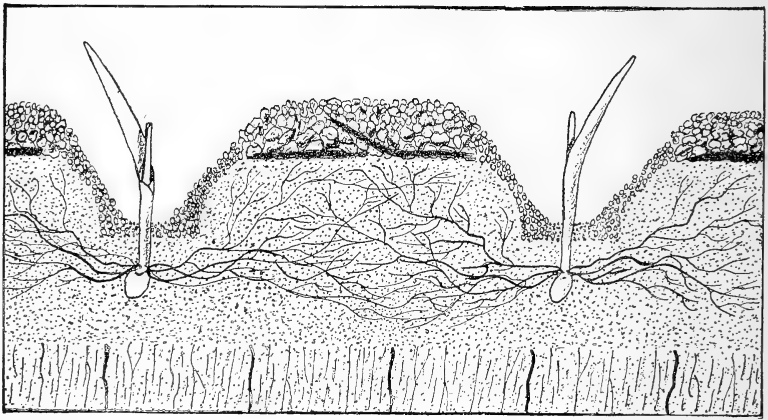
and we have noted instances when three-fourths of the stalks or stools would die down in a single hot day simply because the root system was too narrow and the movement of moisture by capillary attraction too slow up to the narrow strip. Because of the excessive heat the demand of the plants for moisture was greater than the condition of the soil could supply, and therefore the little strip becomes depleted of its soil moisture and down goes the plants one after another to the number that can be fed by the available moisture through the present root system.

In the next section we see how the closed heel shoe drill has deposited its seed into the fine firm moist soil. The root system in this condition is not only perfect on the start, but is lasting because the entire plowed portion has been made fine and firm to the very bottom. These points mean much when you consider all kinds of seasons. Farming is not successful farming until you are able to overcome all possible conditions that tend to a small crop.

LISTING WHEAT.

During the past few years of desperate efforts to overcome drouthy conditions and to if possible improve on the methods of insuring annual crops, there have been a number who have tried the plan of putting in wheat with a lister. In cut No. 18, we show the plan more for the purpose of putting some inquiring minds right as to the real merits of the method in the conditions which follow. It is claimed by the most sanguine advocates that the great advantage is that the rains run down into the bottom of the furrow, then on into the soil below, to the roots of the plants, and cause a strong healthy growth. But close investigation shows a root development similar to that shown in the cut, and that instead of the real feeding ground being below the furrow, it is in the ridges between the

furrows, because here it is that the most ideal condition exists. The mulch that lies over the top of the ridge prevents the moisture escaping even more completely than in the bottom of the furrow after a good rain which dissolves and packs the soil in the bottom. In the ridge between the rows it is never too wet and always moist, as long as moisture exists below and with the proper proper-



Cut No. 18. Showing Growth of Listed Wheat.

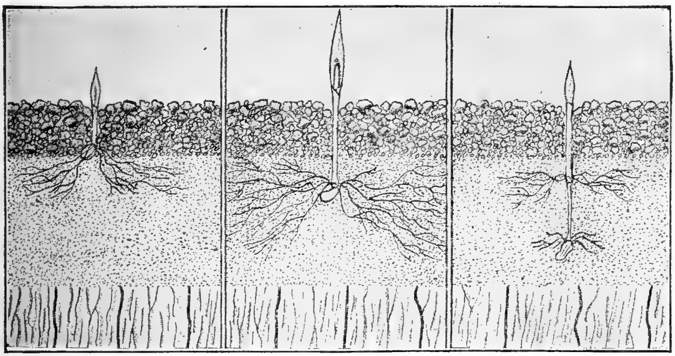
ties of air, water, heat and light, fertility is available. Don't ever be misled into the idea that plants feed especially close to the plant body, but rather where the most ideal conditions exist.

Then again be careful to observe all the facts before drawing a conclusion. Any scheme that will provide the proper proportion of moisture below has an advantage, but bear in mind that moisture is not the only element to court.

PROPER DEPTHS OF SEEDING

Very much could be said on the subject of the proper depths of seeding, for the reason that when you make a statement as to a certain depth it must be followed with many ifs, pros, and cons; therefore we bave provided cut No. 19 as a base of argument. In this illustration, however, we assume that we have the ideal soil condition.

At one end may be seen the seed too shallow. Under this condition germination is slower and the plant is more



A B C

Cut No. 19. Effect of Different Depths of Seeding. (a) Too Shallow Seeding. (b) Proper Depth of Seeding. (c) Too Deep Seeding.

quickly affected by excessive heat. If the entire soil was fitted in the more common loose way this seed would have a hard time to exist in case of dry weather.

In the center we have the more ideal condition. Here germination is more rapid, a perfect root system, and practically no loss of time, while at the other end the seed was put too deep. Germination being somewhat slower, a longer period is required for the first leaf to reach the sun-

light, then when it gets to the proper stage for growth, a new set of roots form just at the point where air, moisture, and heat seem to mingle in the most ideal quantities. Here the complete system of feeding roots is established and the root or stem from there down to the kernel withers and dies.

What is here shown regarding wheat is also true of all other grains, corn included. One of the main points we wish to establish here is that depth of seeding does not establish the depth of rooting.

HARROWING SPRING WHEAT

The harrowing of spring wheat is not today a common practice. Some wheat growers have never heard it agitated, but more do not believe it can be done without causing a permanent damage to the crop; and yet we have noted and watched results where a part of a field was harrowed and a part left unharrowed, when the final yield would show more than double where it was harrowed than where it was not harrowed.

The harrowing of wheat and all other small grain is a subject of vital importance, but like all other branches of soil culture there is a right and a wrong condition, a right and a wrong time, a right and a wrong manner of harrowing.

SOIL CONDITIONS

The first condition to consider is the soil condition. Just a glance at cut No. 16. The soil at what we term the root bed is here shown fine and firm. Note the root system. In case of a heavy rain that would dissolve and settle the loose mulch, thereby assisting the loss of our stored water below, as well as shutting the air out. Something must be done. Just as soon as the surface is sufficiently dry so the soil will not stick to the harrow this

field must be harrowed. While you may destroy some plants, the loosening up of the surface brings back that ideal condition for the development of plant elements that means so much to the growing plant, and it would be better in many instances to destroy one half of the grain and give the other half a good chance, than to starve out all the plants.

That soil condition most favorable for the perfect root system is most favorable for harrowing. Never harrow after the surface has become dry and hard, but always when moist. This is almost invariably possible at some opportune time.

THE WEEDER

There is no place where the weeder that is properly constructed plays its little part so completely as upon a field of wheat or other small grain which has been put into a field that has that ideal condition and the proper quantity of seed has been sown. The surface can be so nicely loosened and yet so little grain is destroyed, because of the flexibleness of the teeth, but if you have no weeder use the common lever harrow. But if your soil has been left so light and loose that you have no root bed, then be careful, for it is better that you summer till the field and get two or three crops next year, than to chance a failure of a crop on a piece of soil so unscientifically fitted that it will not permit of harrowing.

TIME OF HARROWING

Care must be taken to catch the soil moist if possible. The best time to harrow is when the grain is beginning to stool, or when three to four inches high.

If, however, the field should unfortunately pass through the spring without rain enough to settle the mulch it is not necessary to harrow. Then again should you get a

heavy rain and harrowing had been done and a second rain should come, it may he necessary to harrow again. The great effort should be to get the foliage of the grain to cover

Harvesting Wheat Fifty Years Ago.

the soil, while the surface is still loose, in order that there may be free access of air to the firm soil. Above all things

don't look upon this air circulation as a mere fad or theory. Its importance and great value has been proven over and over again in our work.

AFTER HARVEST

When a crop has been taken off, get on this ground as quickly as possible with the disk harrow. Double-disking is exceedingly valuable. The small size disk, fourteen or fifteen inch, set at a good angle will quite thoroughly pulverize the ground, but with the larger disk it is impossible to get a good condition without double-disking. Remember that the object is to thoroughly pulverize the surface two or three inches, to not only prevent the loss of any moisture we may have below, but to have the ground in the best possible condition on the surface for the rapid percolation, or getting of the rain waters down into the soil. Lose no time after any rain in again loosening the surface, especially upon any ground that you may have already plowed. After the disking, plow and pack and harrow, as stated with reference to summer culture. Should you get any heavy rains late in the fall, lose no time in loosening the surface to save the water, for you may need it the following year.

When spring time comes get over your ground as quickly as possible with the harrow, aiming if possible to do this before the surface gets dry, put in your seed, not too thick, and await its developments when it reaches the stooling point, which it will do early in the season if your ground is in the proper condition. At this point of growth, that is when the wheat is beginning to stool or sucker, go over your ground with a long-toothed weeder. This will loosen the surface and destroy the weeds. The checking of evaporation by this cultivation will urge on your wheat, when it will soon cover the ground, then the danger of

evaporation is much less. The rich prairie soils of the Dakotas, Minnesota and other sections of the northwest should produce thirty to fifty bushels of spring wheat

EASTERN COLORADO WHEAT
Crop of Forty-eight Bushels per Acre in Eastern Colorado in 1906 Without Irrigation.

instead of five to twenty, and will if the soil is properly handled. A thirty bushel crop should be got any year.

Don't think for a moment that you can get this rapid growth and early heavy stooling of the wheat unless your ground is thoroughly fined and firmed and you have held the moisture below, forming a seed bed in which there will be a rapid developmtnt of strong roots which is the direct result of prolific stooling. The use of the weeder or harrow on wheat after it has begun to stool, or is three or four inches high, when your ground is loose and porous

WYOMING WHEAT.
Showing What is Being Done on the Fine Prairies Without Irrigation.

where the roots should grow is not always a safe proposition. The root development is so light that much of the wheat may be easily pulled up and destroyed.

WINTER WHEAT

Winter wheat is a little different proposition from the spring wheat. Here again we believe when the farmer in the winter wheat belt has learned the value of summer

culture, and how it will not only greatly increase the average yield, but make a failure, so far as drouth is concerned, an impossibility, a larger acreage will be thus treated.

This part of the Campbell system of soil sulture if carried out to the letter in the winter wheat sections, especially where the crop will ripen in time to finish cutting in June, will certainly revolutionize wheat growing, not only in the more arid sections, but in the more humid sections.

The plan should be in case of old land, to summer till about one-third of the land thoroughly each year until the entire field has been gone over, then follow closely the following plan: As soon as the crop is harvested, double disk the field; better still to follow the harvester with the disk; harrow or otherwise cultivate after each subsequent rain, until as near as it may be possible to the middle of July; then plow and follow same plan as is laid down for summer culture, and seed again at proper time.

This line of work if carefully followed after one season's thorough summer culture will result in further big crops, because the disking, plowing and other cultivation during July and August and early September, gives opportunity for further development of plant elements as well as storage of miosture for the next crop.

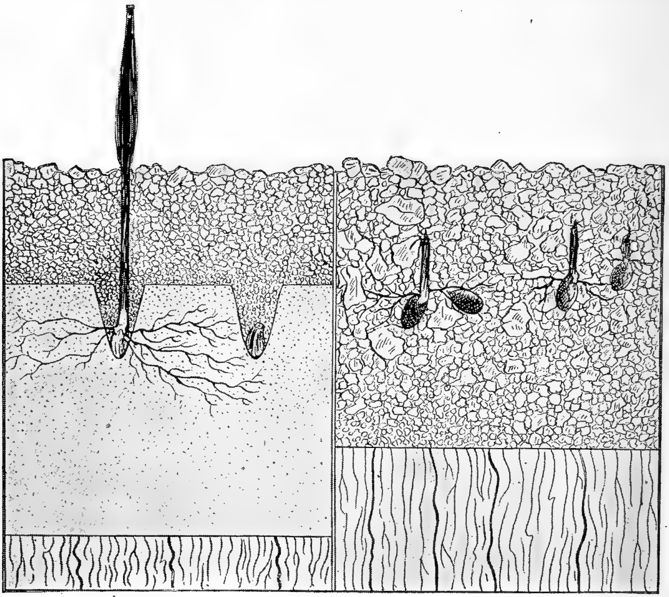
The experience on the Pomeroy model farm at Hill City, Kansas, for seven years, 1900 to 1906 inclusive, at the Burlington farm at Holdrege, Nebraska, from 1903 to 1906, inclusive, and many other points in western Kansas and Nebraska, and eastern Colorado, and the Panhandle of Texas, are certainly evidence that our ideas drawn from twenty-seven years of experience and observation, represent something more than theory. They at laast carry

very strong evidence as to thevalue of this class of work, where, by this very careful preparing of the soil, having plowed about seven inches deep, followed our plow closely with the sub-surface packer, and the packer with the harrow, going over our fields immediately after the heavy rains or as soon as the soil was sufficiently dry to permit it,

The 1904 Wheat Crop, Pomeroy Farm, Kansas.

we had formed a fine, firm and very moist seed bed. Under these conditions twelve quarts of seed was found to be ample. Its germination was so quick and the rapid development of roots brought about by the very favorable physical condition of the soil, caused the liberal stooling, and in thirty days after seeding our ground was nearly or quite covered with the wheat. The immediate disking

after the winter wheat crop is removed is of very great importance; as we have repeatedly said, it is of two-fold value, as it prevents the loss by evaporation of any moisture in the soil, and puts the surface in the best possible



Germination of Wheat in Soil Properly Fitted and in Loose Soil.

condition for the rapid percolation of later rain waters. The plowing may be done a little later, and to get the best results a good depth of plowing is necessary, and then the plow should be followed with the sub-surface packer. Mark you, we are after a condition that will not only enable us to get the best possible results, but prevents any damage by drouth and assures good crops annually, which means

prosperity in its highest degree. A fine, firm seed bed, or root bed, has many advantages over the coarse, loose condition.

In the first place, one-third only of the seed is necessary. in the next place the growth and development of the plant is much more rapid, and will soon cover the surface. In the third place, the development of roots is much greater, we are able to draw moisture and plant food from a much larger percentage of the soil, and last, but not least, we have a condition of soil that will hold a much greater per cent of moisture as well as one having a greater power of capillary attraction, enabling us to keep up the supply of moisture which we draw from below, where, by careful work, much of the rain waters are stored,, that under ordinary conditions would have been lost by evaporation or run off.

WHEAT—THE PIONEER'S MONEY CROP

Wheat is the money crop for the pioneer and will surely put him on his feet if he will but follow Scientific Soil Culture to the letter, whereby he makes the crop a sure one so far as the general climatic conditions may go, but when once on his feet he should change to mixed or real farming.

BURNING STUBBLE

The question of burning stubble has received quite a discussion in many localities. This, however, is a one-sided question. Stubble should never be burned, as it is sending up in smoke what means much to the soil.

The usual and only difficulty is overcome entirely by the use of the sub-surface packer. See cut elsewhere.

We not only oppose burning stubble, but favor cutting the stubble just as high as possible, that just as much

vegetable matter as possible may be returned to the soil, and when you get a crop after summer tilling running 40 to 60 bushels per acre then cut it as high as you can. You can bank on increasing the humus to some degree with the enormous root growth together with the straw.

CHAPTER XXII.

GROWING POTATOES.

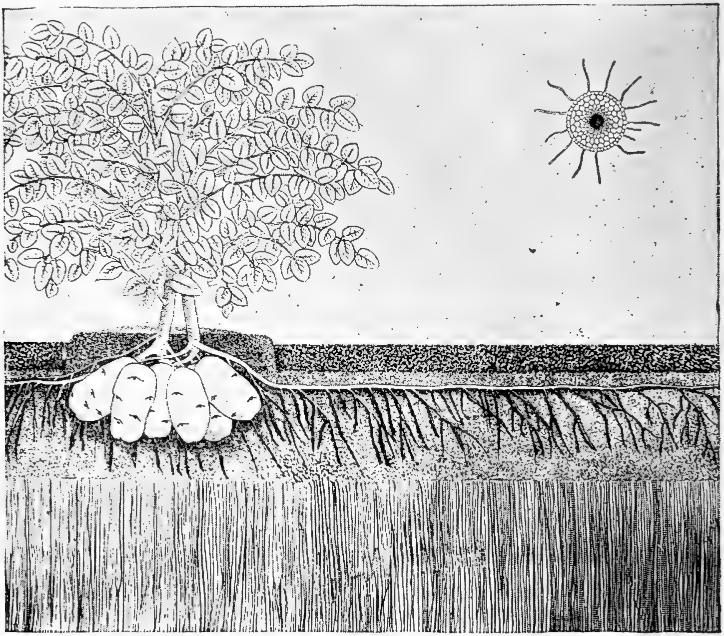
The potato is another crop which in the catalogue of the the western farmer is too often listed with the things which he thinks can only be grown where there is an abundance of water in the soil for the plants and to waste. The potato is a strong grower and does require a great deal of soil fertility, but it is not a crop to be confined to the more humid regions.

There are persons who have been insisting for a long time that the only thing to do if potatoes are to be grown in the west to supply the demand for home consumption, some new variety must be developed or imported that will better suit the climatic conditions. This is a vain hope except so long as little or no attention is given to the vitally important matter of the proper fitting of the soil for the crop.

Of course there is always danger of loss from the ravages of insects and from leaf or tuber diseases; but it can be safely asserted that these dangers are not as great in the semi-arid belt as in other parts of the country generally. In fact the better preparation of the soil made necersary here and the perfect cultivation which must be followed for success, practically insures against loss from any of these various causes.

In fact, many farmers have been making a success with potatoes in the semi-arid belt for a number of years. The writer has knowledge of instances in southern Nebraska

where in the spring of 1901 there was almost entire absence of rain, yet one 20-acre field averaged 100 bushels per acre, and the potatoes were sold at $1.00 a bushel. This was with cultivation under the Campbell method; while all around the potato crop was a total failure. There



Cut No. 20. Root Development with shallow cultivation.

is really no reason why good crops of potatoes cannot be grown all the way from the Texas line to Canada, with right preparation of the soil and care in cultivation during the growing season.

PREPARING THE SOIL

The preparation of the soil is, in growing potatoes as in almost everything else, the chief matter for consideration. In the chapter on sub-surface packing will be found illustrations of the different ways of preparing the soil for the root and seed bed, from which the reader may gain a good idea of what is meant. While we have said much upon the importance of a proper condition of the soil when all work is done, we must almost repeat it again, because so very much depends upon this to secure fineness, firmness and moisture in the soil such as may be most favorable to a rapid and full development of roots such as will lead them to permeate every part or portion of the soil.

In the ideal root and seed bed as shown in the cut the soil was plowed eight inches deep, after having been thoroughly disked to a depth of fully three and a-half inches; the disking having been done early our soil was moist and was in the best possible condition to plow; as the furrow rolled over the fine, dry top soil went under, the moist soil coming to the surface in an ideal condition, and while moist the particles seemed to readily separate one from the other and adjust themselves without material resistance to the desired compactness, as the packer wheels rolled over the plowed ground, which was done quite close to the plow.

In the illustrations given we have been able to show only the main lateral branches of the roots. The little hair roots or feeders may be found in such soil running in every direction, so completely filling the soil as to draw moisture and plant food from every portion.

In the cut in this chapter, where the soil and roots are shown highly magnified, is something that will bear study by every farmer. It represents at the right a section of

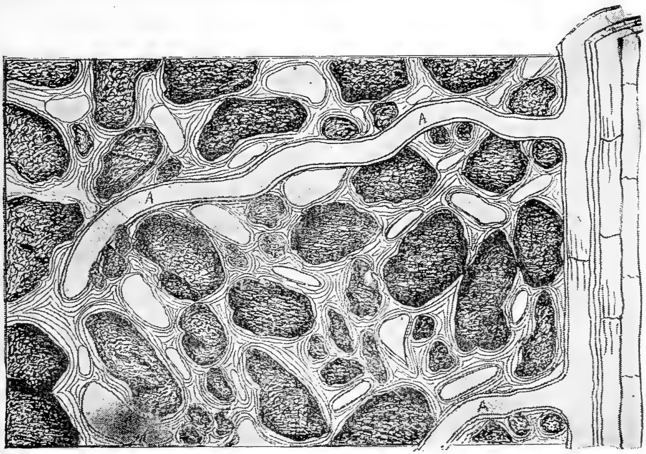
a branch root showing the cell formation; from these outer cells are the hair roots or feeders A A, running through

Cut No. 21. Deep Cultivation.

among the particles of soil represented by the dark spots; around these spots are lines parallel with the shape of the particle of soil which represent the film or covering of water. The white spots represent air spaces. Now, if the reader will look at this cut and think for a moment that these hair roots or little tubes marked A A in their full size in the soil are barely perceptible to the naked eye,

and then imagine that these soil grains and air spaces here shown are proportionately smaller in their real soil condition, he can gain a good understanding of what is the ideal condition of the soil to which he has been laboring.

If you are after a sure crop, as well as a good crop of potatoes, get your root bed as near this condition as possible.



Cut No. 15. Magnified Roots and Soil.

Having previously succeeded in storing a liberal amount of moisture in the soil below, as shown in cut No. 8, you can plant your potatoes knowing you have done all you could do to assure success so far.

SEED AND PLANTING

The planting of potatoes can be done at the time of plowing if desired, by simply dropping the potatoes on the side of the furrows about three inches from the bottom, so that the next furrow will cover them. Better results, perhaps, will come from more complete preparation of the

ground, as for any other crop, then planting with a potato planter about four inches deep.

As to variety of potatoes it is well known that there are a number of excellent varieties, and one farmer may have a preference for one while another farmer is sure hit kind is the best. But almost any of the standard varietiet will do. In selecting a new variety do not get one thas has not been sufficiently tested. It is well in trying ous new varieties to begin in a small way and work up for seed. The Early Ohio is an old standard variety, but it is not the only good one. For seed we prefer large potatoes, cutting them as near two eyes in a piece as convenient, then planting one piece in a hill. For the more arid portions of the semi-arid belt we would plant the rows about three feet ten inches apart and drop the seed, cut as above, about twenty inches apart. In the lower altitudes, or where there is a greater rainfall, plant somewhat closer. Remember, the one great point is to never let your potato plant lack for water. If you do your crop suffers. Small and knotty potatoes are the result of the potato plant getting short of water at certain times, which tends to force the ripening or maturing period. Then a sudden and heavy rainfall or the irrigation of the potatoes after this condition forces a new and rapid growth which results in setting a second lot of potatoes, some of which may appear on the roots and others on the sides of the already formed potato.

CULTIVATION

Care should be taken in cultivation of the potato not to destroy the roots. The potato is prolific of roots, and these reach out into every part of the soil between the rows. Too deep cultivation will destroy many of these roots, especially after the plants have grown to a consid-

erable size, while shallower cultivation encourages the plant to send out its roots laterally so that the value of late rains may be realized most quickly. There is no better tool in the early cultivation than the harrow or weeder, if you will use it freely and with some judgment. The long toothed weeder may be used from the time the crop is planted until the tops are too large to draw between the teeth, providing you catch the soil in just the proper condition, especially in the average sand loam soils. Should you get a very heavy rain that may result in packing the surface to a considerable depth, then it will be necessary to cultivate with some fine tooth cultivator, as in cultivating corn, but in such case it is well to follow the cultivator closely by crossing the rows with the weeder. This more completely fines the mulch as well as levels it, also loosens the soil among the vines, and cleans the young weeds. Watch closely the condition, however, and be sure to keep the soil stirred deep enough, even if it is necessary to use the cultivator; a mulch of fine, loose soil of fully two and a-half inches in depth should be kept as soon as the potato tops get to any size, and the soil should be stirred often enough to keep the top of the firm soil beneath the mulch in a moist condition. This condition can be kept if you have moisture stored below, and do not plant too thick and watch your time of cultivation. Upon the care and attention given over to this part of the work depends the quality and quantity of the crop. Don't stop cultivation when they are in blossom, but don't destroy the roots.

If you want to raise a prize crop put them on a piece of summer tilled ground, plowing again in the spring fully eight inches and handle as suggested.

CHAPTER XXIII.

TREES ON THE FARM.

Plant trees! It is old advice, and ever good. It was the best possible advice for the pioneers of New England when they planned their farm homes; it was still better for those who went into the valleys of the Ohio and Mississippi and converted the prairies into gardens. And so it is the best advice to be given those who are making homes on the great semi-arid plains of the west. Wherever the trees will grow and flourish there can be agricultural pursuits; and trees can be grown anywhere in the semi-arid country.

Shade trees and for shelter and ornament ought to be on every farm of this region. We have abundantly demonstrated, and can furnish the evidence that will convince the most skeptical that fine trees for this purpose can be grown in five years in regions regarded generally as the most unfavorable for tree planting. And what is there that can add more to making farm life pleasant and satisfactory than a lot of shade trees surrounding the farm house, so that at the noon hour or in idle moments the farmer may rest out in the open air in the shade of a fine tree. Those who have first looked upon the barren plains of the west have regarded this as only a dream; but the dream is a reality on hundreds of farms.

Then as to trees for fruit, and with these the small shrubbery of the garden for small fruits of various kinds, and the vines. Good orchards are being grown in the semi-

arid region under the system of scientific soil culture as we have demonstrated. The problem is a little different from that of orcharding in the older states and where there is moisture to waste, but intelligent application of the principles which are necessarily followed in farming under semi-arid conditions, will inevitably point the way to success in the growing of orchards.

Trees for fruit and ornament and for the wood, have transformed the praries of Iowa, Illinois, Minnesota, Missouri and eastern Kansas, Nebraska and the Dakotas, until the very face of nature seems different. What has been done here can and will be done further west where it is commonly supposed conditions are not so favorable. It will be shown that conditions are favorable, if only we know how to take advantage of these conditions.

The traveler who journeys over the region along the eastern line of Colorado and further west and who is able to compare the appearance of the country with what it was only a few years ago, must be struck with the change which is taking place already, and if he understands what is possible he can easily picture the still further improvement possible in a few years. No farmer living in this region who possesses any enterprise or any pride in his surroundings but has now a fine grove or orchard, or both, and trees healthy and beautiful.

PRACTICAL WORK

The test of tree growing is found in practical experience. Some remarkable results have been attained and these are well worthy of consideration by everyone at all interested in the subject. An experience at the Pomeroy model farm near Hill City, Kansas, covering a period of five years or more will illustrate well what can be done. The land selected for the buildings around which a large

number of shade and ornamental trees were set, and for the orchard, is on a high divide overlooking the town, with quite a considerable south slope.

The south slope is much more unfavorable than the north, as it gets the rays of the sun more directly and catches the force of the south winds during the extreme heated portion of the season; but this south slope was purposely selected that visitors might see that what could be done under such conditions might be done at any point. For the most successful growing of trees or orchard a northeast slope should be selected as most favorable.

The ground for our trees was first double-disked early in March, 1900, plowed in April about eight inches deep, the plow followed by the sub-surface packer, and the packer with a good harrow. The ground was then laid out by using the check chain of a corn planter. A small stake was set for each tree or shrub, and nine hundred and sixty-four of these stakes were thus set.

When the trees were received from the nursery a deep trench was dug and all trees heeled in with tops pointing north. Care was taken to keep the roots from the air, and what is most important, to keep them moist. When taken from the boxes they were quickly covered with dirt, and water turned on. A kerosene barrel was sawed in two parts, each half barrel was filled about two thirds full of water, and sufficient dirt was added to form a thin solution of mud. when the trees were taken from the trench when the workmen were ready to engage in the actual work of setting the trees, and put into this solution one by one, and enough mud adhered to the roots to keep them protected from the air and sun while being handled during the process of setting.

SETTING THE TREES

In setting the trees in the orchard two boards four feet long by six inches wide were provided with a notch in the

Peach tree, 5 months after setting, Pomeroy farm.

center and a notch at each end, both boards being cut exactly alike. The man who dug the holes used one of the

boards, and placing the center notch on the stake pulled the stake out and set it in one of the end notches and added another stake in the other end notch. He then removed the board and dug the hole.

In digging the hole the tree was examined to note the size and shape of root and hole dug sufficiently large to allow spreading all the roots out their full length and no more. The man who directed the tree setting carried the second notched board and after the hole was completed he placed the board on the two stakes, and dropping his tree into the hole brought the body to the middle notch, thus holding it exactly where the original stake had been set,

In setting a tree a helper using a hoe pulverized the dirt that was still fresh and moist, hauling it to the roots as fast as a man could place it in with his hands and by the aid of a trowel. Great care was taken to work the soil in about roots. When sufficient dirt was in to cover the roots a quart of water was turned in. By vibrating the tree slightly the water soon percolated through the moist soil, dissolving the particles and settling them closely around the roots. The holes were then filled within two inches of the top, and then tramped firmly. Then about three inches of loose dirt was scattered over this packed soil, and the tree left.

This plan was so successful that in the spring of 1901 we were obliged to reset only seventeen trees, less than two per cent, the trees all having made a very fair growth the first year. The expense of caring for these trees in 1900 outside of the trimming, but including all other work and cultivation, amounted to $22.00, or about $2.25 an acre.

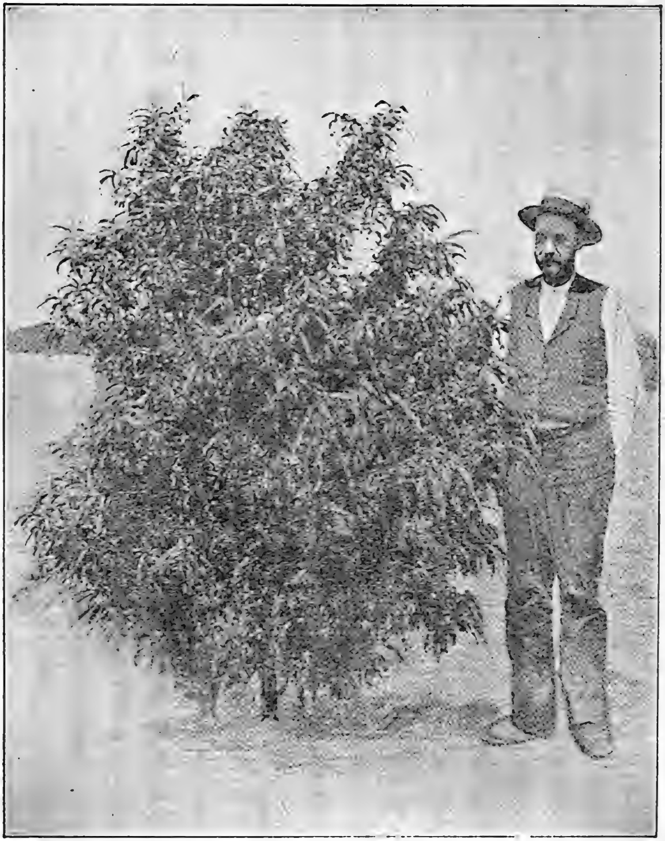
CARE OF SURFACE

The plan of operation was immediately after setting the trees to double-disk the entire surface, because the hauling of the wagons and the tramping of the men over the moist soil while setting the trees resulted in packing the ground considerably. A two-horse disk was used for this work, which enabled us to get very close to the tree. As soon as a rain of any magnitude had fallen, the ground was gone over with the pulverizing harrow, crossing the work done with the disk. This harrow is a tool pretty generally known, and a most valuable instrument for this class of work. No weeds were allowed to grow. About two and a-half inches of the surface was kept constantly loose and fine by the use of the harrow until July, when a second double-disking was applied. The object of this occasional disking was to cut deeper to prevent even the slightest degree of crusting beneath the mulch. Then the harrow was used, going at right angles each time with the previous cultivation until September Ist.

LATE CULTIVATION

Up to this time we had been inclined to follow the ideas of most orchard and tree men and horticulturists, which was to discontinue cultivation after August, the object being to check the growth of the tree and allow the new wood to mature before freezing time. This idea presumably is correct in the more humid portions of our country. But in the semi-arid section we are inclined to discredit this theory in its full extent, especially where the rainfall is below fifteen inches. We believe the cultivation should be continued, but less frequent. We must not lose too much of the moisture from around the main roots and their branches, if we would carry our trees safely through

the winter. This question is a nice one and must be treated with care. It is proper to reduce the sap in the body and limbs slightly, but there is danger in going into the winter with soil too dry about the roots. Much atten-



Peach tree, Pomeroy farm, 17 months after setting.

tion has been given to this point by most of our agricultural colleges the past four or five years.

From Bulletin No. 52, issued by the University of Illinois in 1898, we take the following. We quote it especially because it corresponds to our own experience and is the result of several years of observation:

"Throughout large sections of Illinois may be found the rotting remnants of once extensive orchards, representing large original expenditures of both labor and money. The frequency with which such localities are met would almost seem to justify the statement usually heard in the neighborhood where such worn out orchards are found that the soil is not fitted for the growing of fruit. On the other hand, the enormous apple and other fruit production in other parts of the state, and frequently in localities not far distant from those mentioned, makes it evident that the reason so often assigned cannot be the correct one.

CAUSES OF FAILURE.

"On examination and inquiry it will be found to be almost invariably the case that the true cause for the failure or the dying out of an orchard is the lack of proficient, or the entire absence of proper cultivation and care. While the Illinois agriculturist has been devoting his time and attention to the care of his field and garden crop, it is too often the case that the orchard has been left to care for itself, with the above mentioned result. The commonest cause of failure in orchards in Illinois may be traced direct to the ill effects of summer drouths, though perhaps it is more commonly referred to as freezing in winter. The connection really existing between these two destructive agencies has not been often recognized. The fact that certain varieties of apples usually accounted

hardy even to our most northern limits, and in exposed situations sometimes fail after a winter not noted for severity, has at different times attracted attention, but the significance of such failures does not seem to have been duly appreciated. On consulting the records it is found that orchard injuries and exceptionally severe winters do not coincide. The autumnal conditions of the trees clearly has to do with the results, and this again depends upon the developments of the growing trees. One of the worst things that can happen to trees is the failure of a sufficient supply of soil moisture. A continuous supply of water is essential to all the vital processes of vegetation. Apple trees severely suffer when not so supplied."

The bulletin continues at considerable length along this line, and then presents two very striking cuts on pages 126 and 127, one showing the orchard upon the college farm with trees hanging full of fruit, the other of an adjoining farm with neglected trees uncultivated, bare of fruit and almost minus of foliage, and the bulletin concludes by referring to the cuts in the following manner:

"The photographs were taken in September, 1897. The tree in the foreground of the college orchard, with its wealth of foliage and bending under the weight of its load of fruit, tells its own story, and stands forth in marked contrast to the preceding picture, which is bare of fruit and almost minus of foliage. From the contrast there can be but one conclusion drawn, that while other things have greater or less effect upon an orchard's health and condition, the prime requisite to successful orcharding in Illinois is thorough and systematic cultivation."

While the principles involved in the Illinois bulletin are important and valuable in that state, they are vital with us in the semi-arid section. The prevailing idea,

and the idea usually drawn from most of our articles, is that the work is too expensive to make orchard growing profitable in the more arid portions of this country. This is quite an error, fully demonstrated by the figures given of our own work in the orchard of the Pomeroy model farm in 1900.

EXPERIENCE IN KANSAS.

In this chapter is shown an illustration of a peach tree grown on the Pomeroy model farm in Kansas, from a photograph taken in the fall after the first season's growth. The tree had then been in the ground five months. The trees in this orchard were all cut back to about three feet when they were set, and all limbs cut back so as to leave but two buds to the limb. The second season's growth is shown in the illustration where a growth of seventeen months indicates a remarkable result. This photograph was taken August 23, 1901. The contrast in growth as shown in these two illustrations ought to be sufficient proof of what can be done in trees growing where the preparation of the soil has been right. It shows that without irrigation orchards may be grown in the most arid portions of the states of Colorado, Kansas and Nebraska. The body of the tree shown as of first season's growth, measured a little over an inch in diameter, while the body of the tree after 17 months' growth measured two and one-half inches in diameter. As the man standing by the tree measured six feet three inches, to the top of his hat, the reader may get some idea of the remarkable growth of these trees. There is no reason why they should not have made this remarkable growth, for, although we experienced a continuous dry period, with the excessive heat of one hundred degrees and above for forty-three days, from June 18 to August 1, entirely without rain;

yet during that entire time the ground was amply moist to make into balls about the roots of the trees, and to a depth of over ten feet. During this entire time, owing to the manner of cultivation and the care taken to save this moisture, this soil was practically as full of moisture about the roots of the trees as it could hold, and had there been previous irrigation from a ditch the soil could not have been more moist.

SHADE TREE RESULTS

The illustration of a white elm tree on the Pomeroy model farm seventeen months after setting again shows what can be done on ground properly prepared and with right treatment of the surface of the soil. Looking closely you can see the man's hand about four feet from the ground, grasping the pole which is ten feet high. At this point where the hand shows, the tree was cut off when set in the spring of 1900. The growth during 1900 was not much, though quite as much as might be expected the fierst year, the new limbs averaging about ten inches. This photograph was taken August 23, 1901, when the tree reached within eight inches of the top of the ten-foot pole. Elms are usually considered slow growth. This illustration is certainly a demonstration of two facts, that they will make remarkable growth with plenty of moisture, and that moisture can be stored in sufficient quantities on the far western prairies to supply all necessary needs of such trees.

In the setting of trees or orchards in the more arid portions of this belt, care should be taken to not get them too close together. A successful growing of a tree depends upon ample pasturage of the roots. In our orchard at the Model farm we set our cherries and peach trees twenty-two feet each way, and our apples twenty-two by thirty-

two feet. No crop of any kind or nature should be grown in an orchard if you would secure the best results. It may seem like a waste of ground to see little two-year-old trees standing two and a-half to three feet high with tops only one foot to eighteen inches broad, twenty-two feet

White Elm tree, Pomeroy farm, 17 months after planting.

apart each way; but when we note the immense growth of our trees the second year we see it is not long before the entire space is utilized. Back of the house where we lived in Holdrege, Nebraska, is a cherry tree that now measures seventeen and a-half feet across from tip to tip of limbs. You can readily see that in the twenty-two-foot distances we only have four and a-half feet left. Now, if you expect the trees to make this growth, you must not interfere with the roots of the tree, or in any way rob it of any of the moisture or plant food in the soil. Besides, to plant a crop of any kind would make the cultivation much more inconvenient and expensive. A trip back to the old Eastern States, even in Illinois, and then on through Ohio and New York State, will disclose a radical change in methods of handling orchards. The most profitable orchards in those states, today, have no crops or grass growing in them; while twenty years ago it was a common practice to seed them down to grasses. If that kind of treatment is desirable and profitable in the east where the rainfall is more than abundant, it is much more desirable in the west.

We can now cite many instances of successful tree and orchard growing in western Kansas and Nebraska and eastern Colorado, but space will not permit. For further evidence of the importance of frequent cultivation of trees read the chapter on soil culture, and for more emphatic evidence of the marvelous growth that can be attained by proper cultivation of both fruit and forest trees, visit the Pomeroy model farm in midsummer and behold the lofty and beautiful shade trees growing there.

The truth is that all over the semi-arid region in the past five to ten years there has been wonderful development in the growing of trees and the care of orchards and groves. Everywhere the fact is coming to be recognized

that tree growing is just like the growing of other things, that it all depends on the care and preparation of the soil and intelligent application of the principles of scientific soil culture. The present error is the inclination to be satisfied with a fair ordinary growth. Don't do that. Get all nature can give up to you.

It is useless to apply commercial fertilizers to lands which are not in proper physical condition for the very best growth of crops.—Prof. L. H. Bailey.

We find by the Campbell system that we can as well keep moisture in the ground as to put it in a jug and put in the cork.—J. B. Beal, Chief Land Examiner Union Pacific Railroad.

Nitrogen Supply.—Considering all these facts and the additional facts that there are about seventy-five million pounds of atmospheric nitrogen resting upon every acre of land, and that it is impossible to obtain unlimited quantities of nitrogen from the air for the use of farm crops, and at very small cost, the inevitable conclusion is that the inexhaustible supply of nitrogen in the air is the store from which we must draw to maintain a sufficient amount of this element in the soil for the most profitable crop yields. —Prof. Cyril G. Hopkins.

CHAPTER XXIV.

SUGAR BEET GROWING.

All honor to those who have been doing much in recent years to develop in the semi-arid belt as well as elsewhere in the states the new industry of making sugar from beets. Nearly everyone is aware of the fact that there is now manufactured in this country a great deal of sugar from beets; but few realize the enormous quantities of sugar made each and every year west of the Mississippi river. The consumption of sugar is increasing rapidly, and the

Thinning Sugar Beets.

demand is almost keeping pace with the supply, so that the possibilities of the business are infinite. Sugar factories are dotting the states of the west. Many more are coming. And it is no longer true that the sugar beet factory must be supplied from roots grown near by, for it is found profitable to ship long distances to factories.

The possibilities of beet sugar production in the west are beyond estimate, and not only by irrigation but with-

40 acre Sugar Beet field at Holly, Colorado.

out irrigation many fields are being developed. In this article is an illustration of a field of sugar beets grown at Lisbon, N. D., on the grounds of the soldier's home by Col. McIlvaine, in 1897, the second year's experiment on the same ground. It was grown under the Campbell method of soil culture and the yield showed the phenomenal returns of 46,000 pounds, or 23 tons, per acre. The illus-

tration shows the wonderful growth. Aside from the value which can be got from the beets for sugar there is also the great value to be got from the feeding of the pulp. Experiments thus far show that this value is considerable, and later experiments may add much to our knowledge of how to utilize it. At any rate it is certain that sugar beet growing will be one of the great industries of the semi-arid west for the next century.

SUGAR BEET CULTURE UNDER IRRIGATION.

The following is a conicse statement of the best methods used in the successful raising of sugar beets under irrigation.

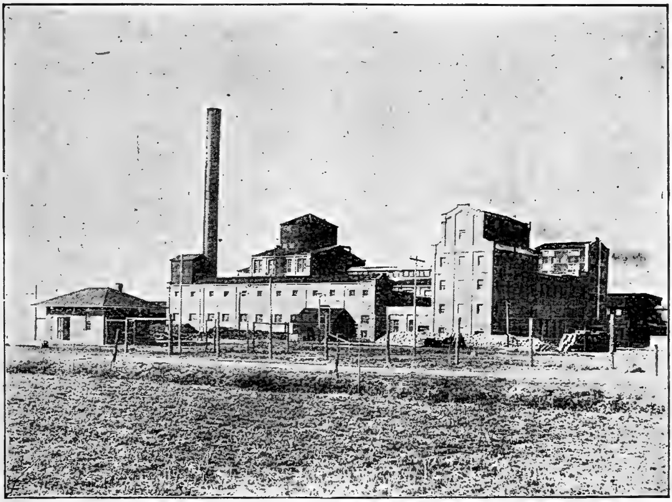
Soil—Always select your best land. Avoid using poor land for growing beets. Also new ground should not be selected as a good tonnage is rare under these conditions. The ground should have been at least two years under cultivation and if possible manured to some extent in the fall. Stable manure is highly recommended as it will very materially increase the tonnage. Never plant seed on land that is sandy enough to blow.

Plowing—As the sugar beet plant derives its life from the soil, deep plowing is urged as it gives the root plenty of room to grow down and absorb nutriment. If possible in all cases the plowing should be done in the fall and the land allowed to remain rough all winter, airing the land thoroughly and letting in the moisture. It also permits the land to slowly settle and pack which will insure better germination.

Levelling—To facilitate the thorough irrigation of a field, it is essential that the ground should be levelled as well as possible so as to leave no low spots where water will stand. To obtain the best and quickest results, it is well to use a harrow and loosen the top soil, after which a floater

may be used to drag the soil from the high knowls into the hollows.

Seed Bed—Probably the most important thing necessary to be done to insure a good beet crop, is the preparation of the seed bed. After the land has been plowed and eveled as explained above, the seed bed may be made by



A MODERN FACTORY.

Factory for making Beet Sugar at Holly, Col. Completed in 1905, most modern construction. Owned by the Holly Sugar Company.

working the soil down to a depth of four or five inches and then packing it well with the use of a heavy roller, thus insuring the capillary attraction for the moisture which will germinate the seed. Be sure that all the weeds are killed before planting the beet seed, otherwise, unnecessary ex-

pense will be entailed aside from the danger to the crop. The seed bed should only be made when the land is moist and in order that the land may not dry before seeding, no more land should be prepared than can be seeded each day.

Seeding—In order to secure a good yield, a good stand is necessary. To do this not less than twenty pounds of seed to the acre should be planted. The time of planting varies a little with the season, but April and May are the usual planting months. Beet drills built expressly for the irrigated country may be secured to do this seeding.

Cultivation—Cultivation answers two very important purposes, the loosening of the crust after irrigation or rain, and the preservation of the moisture in the ground. Special one horse cultivators are used for cultivating beet fields. A field should always be cultivated as soon after an irrigation or rain as possible in order to break the crust which has formed and allow the plant to grow and breathe, and at the same time it serves to kill the young weeds as they come up between the rows.

Thinning—Thinning of the beets takes place usually about four weeks after seeding, when the young plant shows four well developed leaves above the ground. In thinning great care should be exercised in the proper spacing and also the selection of the hardiest plant to be left in the ground; also to see that the plants that are left are disturbed as little as possible. Thinning done at the right time means a great deal towards securing a heavy tonnage and sweet beets.

Hoeing—In case the ground is very foul part of the field, if not all, may have to be hoed before cultivation takes place. This hoeing should be done carefully so as not to disturb the young beet plant.

Irrigation—It is much better for beet land if it can be irrigated in winter before seeding takes place. Irrigation should be delayed as long as possible after thinning, and

Sugar beets, 23 tons per acre, by Campbell method.

flooding at all times should be avoided. The best way to irrigate is to run the water down the furrows between the beets which irrigates the roots without touching the leaves of the plant, as when the plant is young it is detrimental to have the leaves wet with irrigation.

Harvesting—Whenever the beets are ripe, which is

determined by analysis by the factories, the beets are plowed up with special plows, topped with a large corn knife at the base of the bottom leaf and delivered by wagon or train to the factory.

Siloing—As all the beets cannot be delivered to the factory before heavy freezing weather sets in, it is necessary to place the undelivered beets, after being harvested, into siloes. The siloing of beets is done by placing leaves and dirt over the beets, leaving a small hole at the top to prevent the beets from sweating. Usually not more than two to three tons of beets are placed in one silo. Great care should be exercised to see that not too much dirt is placed over the beets until the weather has turned exceedingly cold.

SUGER BEET CULTURE WITHOUT IRRIGATION.

The growing of sugar beets in the semi-arid section without irrigation can be conducted by following practically the same instructions embodied under the heading ofc 'Beet Culture by Irrigation," except instead of irrigating, giv'e a season to summer culture, storing carefully the season's rain-fall, following carefully the general instruction under summer culture. Plowing, however should be eight or nine inches deep, follow with the packer well weighted, then work the surface with the common harrow aiming to reach the condition shown in Cut No. 4. Balance of the work should be practically along the same lines as suggested under irrigation.

In cultivating such fields great care should be given, not only to cultivate soon after rains, but watch the surface of the hard soil under the mulch and just as soon as it shows dryness it should be cultivated again to prevent a crust from forming under the mulch, which it is liable to

do in prolonged dry periods. Some very marked results have been accomplished by this method, while the tonnage is not quite equal to that from scientific irrigation, yet the yields of sugar is much better. The growing of sugar beets without irrigation in sections where the sugar beets can be easily marketed, will, in the near future, be very commonly practised.

The Pomeroy farm certainly proves the truth of Mr. Campbell's theories, or else he is a wizard.—Wm. E. Curtis.

Your great work in soil culture is thoroughly appreciated by every thinking citizen of Nebraska.—The late J. Sterling Morton.

The Campbell system is a glorious success. It is not a mere wet season humbug, destined to collapse with the next series of dry years. I have doubted, watched, investigated constantly for nine months, and have become convinced that it is the greatest agricultural discovery of recent history.—John E. Leet, in Denver Republican.

CHAPTER XXV.

ALFALFA.

In 1895 alfalfa was little known in the United States except in remote localities. A few had begun to realize something of its value not only as a great hay or forage producing plant, but as a fodder of unusual feeding value. Not until 1900 did our people begin to grasp the real value of the plant which was never well established until careful experiments were made by the State Agricultural Experimental Stations in a large variety of feeding tests.

In no case was any other hay or fodders found to be its equal except for working horses. Its producing powers are far in excess of all other hay when conditions are right.

In its early culture and growth it was considered to be a low land or water plant. Little by little, however, it has gone into the prairies until today there are many fields of ten, twenty, fifty and a hundred acres on the high divide in the more arid sections; in some instances two and three hundred feet above sheet water. In Kimball county, Nebraska, twenty four miles from the Wyoming line, is ten acre field now five years old, 312 feet from sheet water with an average rainfall of 14 inches. This field has cut from one to two and a-half tons of No. 1 hay each year. It is disked once and harrowed twice during each season.

This is only one out of many similar cases, showing conclusively that with careful fitting and good care alfalfa is a most desirable plant.

Alfalfa, like all other crops, thrives best under the most favorable conditions. There is probably no point in the raising of alfalfa more important than that of securing a good stand. It seems almost impossible, in fact, climatic conditions must be very favorable, in order to get a catch of seed in reseeding spots among well rooted plants. There is no seed that responds, or returns greater rewards for a good seed bed than alfalfa, and yet it is a very simple proposition, and if the proper course is pursued and good seed used, there is practically no question about securing a good stand. The summer culture plan, by which one season's rain is stored in the ground, and the soil carefully prepared as outlined in the chapter under this heading, then sowing the seed the following spring, taking care to loosen the surface soil the first opening of spring is best. The best results we have ever seen in western Kansas have come from seeding early in April on ground thus prepared, with ten pounds of seed put in with a shoe drill with a chain cover.

PLAN OF SEEDING.

The next best plan is thorough culture from early spring to July, together with careful preparation, then seed in July with ten pounds of seed with drill or twenty pounds if broadcast. At the time of seeding the above field there were about two inches of loose, fine soil on the surface made by the use of a common harrow, and the shoe set so as to put the seed from one-half to one inch into the solid, fine moist soil beneath. The seed came up quickly and very even, and if there was any complaint to be made it was the fact that it was too thick. With the prevailing price of alfalfa seed the saving of a few pounds of seed is a great item, especially in putting in large fields. The further fact that when once sowed and the crop estab-

lished, it is there for years to come, certainly is sufficient argument to support the demand for thorough and careful preparation of the seed bed.

The summer culture idea involving this storage of one year's rainfall puts the soil in such condition for five or six feet down that the tap root immediately pushes on down through this moist soil sending out the little feeders on their way down, and the chances are that a good crop may be harvested the first year, as was true in the case above referred to, due only to the fact that the soil conditions were perfect for the rapid development of roots, and ample moisture to produce this magnificent growth. While it is true that much better results are attained from alfalfa in valleys where sheet water is eight to twelve feet from the surface, yet a sufficient number of experiments have been made and in some of them a sufficient length of time has elapsed, to warrant the statement that on the majority of our high divides in the semi-arid belt as good or better yields can be secured from this crop than are commonly harvested in the eastern states on the average meadows of timothy and clover. The value of lands where the phenomenal crops or yields of alfalfa along some of the valleys in western Nebraska and Kansas has hardly come to be understood, or fully appreciated even by the people who have raised them. We are familiar with fields that for three successive years have turned off in alfalfa hay alone from $30 to $40 per acre, and where hay and a crop of seed has been harvested as high as $80 per acre has been made. The value of this plant for feeding hogs, cattle, and sheep is just beginning to be appreciated. All experiments thus far carefully conducted have demonstrated that there is no fodder plant so valuable.

PREPARING THE FIELDS.

The preparing of fields for seeding to alfalfa on old ground cannot be better explained than in the instructions under the heading of Summer Culture for spring wheat to which we refer you. As stated above, alfalfa responds quickly and liberally to favorable conditions not only with reference to ample moisture, but the more available fertility the stronger is your plant and the more sure are you of an even stand.

Under no conditions can a man afford to slight the fitting. A common remark is, "I haven't the time." Stop a moment and fairly and honestly consider what this means. No one can tell what this season or the next will be, therefore don't forget this one fact, that if you do not do such necessary work as will guarantee a perfectly healthy stand under any and all conditions, you are liable to get such dry and otherwise unfavorable conditions as to cause a complete failure. Have you gained anything by slighting the preparatory work if you lose all your crop? All your time and seed counts for nothing, you are a year behind, and no alfalfa for the hogs after all.

Let us look on the other side—begin in the early spring and follow closely and carefully the rules for summer tilling and put in your seed either in August or early the following spring. The latter we prefer, especially in sections where summer and autumn rains are common, the principal reason is that we are less liable to get a heavy packing rain after seeding it and before it comes up, which is very serious.

We have seen fields absolutely ruined by the heavy rain followed by hot sun just before the seed comes up. In sections where the heavy rains are common in spring, and less liable or very rare in midsummer and early au-

tumn, as is true generally on the Pacific slope, then by all means seed in August.

If the early spring is unusually dry, then plan to seed in the spring. Remember this fact that planting in summer tilled soils properly handled the germination is quickest, and early growth is most rapid when it is clear sunny weather and no rain. With the more common methods of fitting without sub-packing, a good rain is necessary to even start the crop.

The difference between the more common methods of fitting and thorough scientific fitting is as broad as the contrast between a safe business proposition and that of gambling on chance games.

SEEDING ON NEW BREAKING.

Alfalfa, like many other crops, may be sown on new breaking the same season the breaking is done and sometimes gives satisfactory results, but considering its uncertainty and the difference in the value of a good crop as against a poor crop and possibly none at all, we are inclined to give over the whole season to preparation, for then a good crop is practically assured.

The proper time to break depends somewhat on locality and the time the heavy rains are expected. As a rule east of the Rocky mountains late fall or early spring breaking is followed with best results. For detailed instructions on fitting, note general matter under the head of plowing. Briefly, the breaking for alfalfa should be about three and one-half inches deep, using every possible means and care to lay the furrow slice flat and roll down solid either with the sub-packer or smooth roller, then disk, but do not set the disk at a sufficient angle to cut through the sod, let the disk lap half, then follow with the

steel lever harrow slightly slanted going both with the disk and lever harrow same direction as the team traveled in breaking. If care is taken in plowing, then in rolling, then in disking, you will have about two inches of loose soil. Harrow thoroughly after each rain. If this is fully accomplished the sod will not only be fully rotted in a very short time, but the top of the sub-soil beneath will also become rotted to a depth of two or three inches. As soon as this is found to be true, then begin back setting or plowing with the stubble plow, cutting about two and one-half inches deeper; follow the plow with the packer as explained under the head of Plowing and Sub-Packing, then follow with the harrow, any good harrow, getting it all fine and firm before it has time to dry out. Look well to the storage of later rains and be ready to loosen the surface in early spring with the harrow and put in your seed fairly early, governed largely by the locality, using not over ten pounds of good seed with a shoe drill and chain cover.

If your work is all well done, as outlined, you need have no fears of the result.

CHAPTER XXVI.

SEEKING NEW ARID PLANTS.

The Department of Agriculture, which is expending millions each year for the benefit of agriculture, has thus far, in taking up a study of the problem of the arid and semi-arid regions, confined itself to two things, namely, irrigation and the seeking of new plants.

All honor to those who have so well directed the expenditure of money to make irrigation farming possible in rich valleys that were lying fallow!

And to those who have earnestly sought new plants that will be of value in dry regions, may they be successful far beyond their fondest dreams!

But it will not do to place great dependence on the finding of plants that will grow in the deserts without application of special methods of cultivation. Indeed, Prof. Hansen, the agent of the United States government, who has been specially engaged in this work a number of years, has warned against over-confidence in this regard.

"We are going to extend the alfalfa belt as far north as we can," said Prof. Hansen on his return from Asia in the autumn of 1906, "and we hope that these seeds will prove all that we expect of them. But there is no use in expecting too much. I would not risk my reputation on any positive predictions; I can only say that we confidently hope that we have found the right thing."

Prof. Hansen was referring especially to the seed of alfalfa and clover which he sent back from northern Asia

It appears that the effort has been found rather to find a quick growing plant adapted to extreme northern summers than one which will defy drouth. Prof. Hansen sent back from Asia the seeds of three kinds of alfalfa, two found far north and growing where there was little rain, and the other growing in the woods. He also brought back seeds of several kinds of clover native in northern Siberia where it is very cold, with short summers and little rain. All these will be tried out in the Dakotas and in a few years seed will be distributed to farmers. Another thing brought back is a coarse potato suitable only for stock food, which is said to grow in a dry northern climate. A visit was made also to the high table land in central Asia, where, it is stated, alfalfa has been grown for centuries under conditions very similar to those found in the semi-arid region of America.

It does not appear, from anything that has as yet been published, that any special information has been secured as to the character of the soil or the methods of cultivation which have prevailed in these regions of the old world where conditions are exceptional.

From what Prof. Hansen has said it may be fairly inferred that he realizes fully that drouth resistance is something that does not inhere alone in plants, but there are other things to be considered.

The fact is that great good can and will be accomplished by the importation of new plants adapted to growth in unusual climates, but this must and will be, by and through cultivation of these plants in connection with systems of soil culture adapted to the regions. Success in adapting Asiatic drouth-resisting plants and grasses will be attained only by making use of scientific soil culture. Putting the two together will be vastly beneficial.

But the quest for plants that will grow right out upon the western and northern prairies and make good crops under conditions of cultivation used in the humid regions or with little or no care, is destined to be a dead failure. The owners of land in this region must understand now, as they will some time, that there are no plants anywhere in the world that will make good crops in dry regions without the most careful preparation of the soil.

Intelligent farmers everywhere will give all possible encouragement to the effort to introduce new and valuable plants, and they will do well to make a study of these plants in relation to the very best systems of cultivation.

CHAPTER XXVII.

IRRIGATION.

There is no conflict or antagonism between scientific soil culture and irrigation. There is nothing in our teachings that need be taken as in any sense hostile to the great development of irrigation projects in the west. Neither is the solution of the problem of the semi-arid region to be found in the adoption of irrigation.

Irrigation farming is being carried on in many of the splendid valleys of the west with great success. The irrigated area is sure to be rapidly and greatly enlarged, and no man can tell what results are possible. The United States government, under authority of congress, has encouraged this by special laws under which irrigation districts are created and favors given to large companies, and by direct appropriation for construction of gigantic dams and reservoirs. That this is money well spent will not be disputed by persons familiar with what is being accomplished.

But it is true that the area which may be brought under cultivation with irrigation is limited, as compared with the vaster areas where ditches are not possible. It is also true that at best irrigation farming is expensive and it necessitates special farming and intensive work in order that it will pay. Under such circumstances the farmers must get immense returns for their labor.

Scientific soil culture and irrigation therefore supplement each other. There are millions of acres of the most

fertile lands, level and easy of cultivation, near to the irrigation districts but which cannot be irrigated without unwarranted expense, which receive ample rainfall to produce fine and profitable crops if the water is properly stored and utilized. These lands will remain useless unless scientific soil culture is adopted.

Then there are millions of other acres of land in the same region, which are now used for farming in some way, where there is sufficient rainfall to make irrigation impracticable, but where the present yield of crops under the old system is not to exceed one-third what it might be if the general principles of our system were fully understood and practiced.

But the value of this system will be still more shown on the millions of acres of irrigated land where best results are not obtained. On these areas irrigation is possible, but the quantity of water is limited, and there can never be enough to carry on irrigation farming by the wasteful methods so common. Scientific soil culture comes in to greatly enlarge the area of irrigable lands by showing how good results can be obtained by much less water.

The fundamental principle upon which the success of this system is based is that of economical use of water, it matters not whence it cometh, whether direct from the clouds or from the flowing streams, ditches, reservoirs, or wells. The first and important thing to do is to get a supply of water stored in the soil to feed, nourish and mature the crop in a period of dry weather; and the second and almost equally important requisite is the ideal seed and root bed, so vital in the success of our system, all of which is necessary in growing crops by artificial application of water required in irrigation.

Of course if the farmer has water to waste, whether

from ditches or clouds, he can be wasteful and still prosper. We do not wish to be understood as saying that a farmer may not get a better crop with plenty of water to turn loose at will upon a piece of ground poorly fitted than he could with the same reckless fitting and be obliged to depend upon replenishing his soil with moisture from the heavens. But that is not the question today with the progressive farmer.

How can we get the greatest results from our soil, the labor and expense being considered? That is the question of today, whether in irrigation districts or elsewhere. And in fact, nowhere is it more essential to guard against waste than in applying irrigation. The expensive thing is water. Seldom is there as much water as there is land. The irrigation area is limited by the quantity of available water. By following methods that will reduce the amount of water needed per acre, the number of acres that may be supplied from a given ditch or reservoir can be increased.

The ideal condition for the most healthful and successful growth of all cultivated crops is a good depth of root bed made thoroughly fine and firm. There is little danger in getting the average sand loam soils, so common in the arid and semi-arid sections, too firm, while some of our heavy clay soils if not properly handled might become too closely compacted, but this kind of soil is not at all common. Previous to the thorough fitting of the seed and root bed see to it that ample moisture is stored below where nature can do her part by bringing it up to the roots of the growing plants by capillary attraction, then keep your surface always cultivated in such manner as to provide as near as possible a fine, loose mulch of soil (not dust), stirring it often enough to keep the moisture up to the top of the firm soil just beneath the mulch. The moment the top of this

firm soil becomes in the least dry there is immediately a process of depositing of salts and other matter between these particles of soil closing the pores and consequently diminishing the quantity of air that should freely pass through this soil to the roots. This condition not only points to the fact that you are allowing the air to be shut out but that you are losing moisture by evaporation from the soil which may be checked by cultivation. In fact, there should be no dry soil above your moisture except what is loose and fine.

Sub-irrigation is being practiced with marvelous results in some instances. This demonstrates clearly that if the irrigator will watch his opportunity and will turn on his surplus water in the fall after his crop has been removed or during the winter or early spring, with the water stored in the soil below and care in conserving the moisture by proper cultivation, fine crops can be grown with very little after irrigation.

Very large crops of winter wheat should be grown on the average soils in Colorado and sections under similar conditions if special effort was carefully put forth to irrigate thoroughly, immediately after the crop is harvested, then double disk as soon as the surface is sufficiently dry to do the work without sticking. Plowing later using great care to pack the plowed portions and harrow the surface while moist, seeding sufficiently early for a good fall growth, then harrow early in the spring, then with one irrigation after the foliage fully covers the surface, sixty bushels per acre should be common under such conditions. In all crop-growing under irrigation, much consideration should be given to the chapters under the following headings: "Physical conditon of the soil," "air and its importance in the soil" and the "water holding capacity of the soil."

PHYSICAL CONDITIONS OF THE SOIL.

The one vital question that the irrigator must consider no matter how much water he may have available is the physical condition of the soil. Plants do not thrive on water alone. A combination of the properties of air and water together with heat and light are the resourceful elements which we have, and must be utilized in proper proportions combined in the soil under proper conditions or we cannot secure the large yields. It is folly for a man to own a tract of land and in addition thereto to own a water-right, and then to use them without securing to exceed one-half or one-third of the best yield of that field; if he himself will only do his part intelligently. The part which he must play is that of preparing the soil, securing that ideal condition which is illustrated in several of the previous chapters by cuts. Following this is that all important part of keeping the surface of the soil in condition to admit the air, the importance of which is fully detailed under the head of "Air in the Soil." At no time should the moisture that is forced into the soil from the ditches by gravity be allowed to return in any quantities to the surface and evaporate.

It is through this upward movement of moisture by capillary attraction that many of our fields which are underlaid with a large per cent of alkali are ruined, this alkali when in a soluble or dissolved condition rises to the surface with the moisture in its upward movement by capillary attraction, and as the moisture leaves in a vapor, the solid alkali is left on the surface.

Too much water is almost invariably applied to irrigating fields simply because we have been led to place all faith in water and water only as the producing power. From all our observations in irrigation, the reading of bulletins and correspondence with people who have had years

of experience in California, Colorado, and many other sections, it is our candid opinion that the average irrigator east of the rockies would produce better results with one-quarter of water he has commonly used, together with the scientific principles of soil culture as laid down under the various chapters in this book. (See Sugar Beets by Irrigation.)

CHAPTER XXVIII.

ARBORICULTURE.

Arbor Day is in fact a national day. The people of nearly all the states give recognition to the immense importance of tree planting by setting apart a day for this work. The late J. Sterling Morton, of Nebraska City, a pioneer of the trans-Missouri country, was the father of Arbor Day, and by his zeal and interest in it he forced recognition for the day everywhere.

Mr. Morton was for more than forty years a resident of Nebraska. At his home, Arbor Lodge, as he called it, is one of the finest groves of trees in all the country. Shortly before his death he wrote expressly for the 1902 Soil Culture Manual the letter which follows, and what he then wrote has such permanent value that it is here repeated. He had become deeply interested in the work being done for study of the soil and for agriculture in the semi-arid belt. He wrote:

Mr. H. W. Campbell:

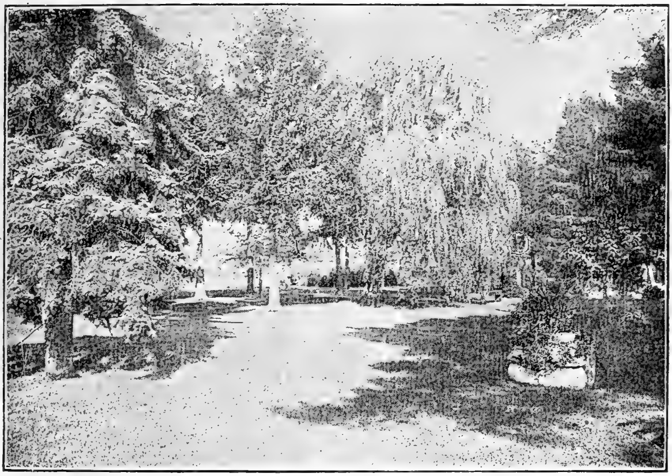
Dear Sir—After an experience of more than forty years at Arbor Lodge, adjoining Nebraska City, in the County of Otoe, I declare that the best method of planting forest trees is in rows running north and south. The first row on the east should be of a rapidly growing variety, like catalpa speciosa, cottonwood, aspen, or soft maple. The next row should be a nut-bearing tree, like the black walnut, butternut, or coffee bean. The next succeeding row on the west should be, like the first one, of a rapidly

THE LATE J. STERLING MORTON.
Nebraska Pioneer, Father of Arbor Day, Secretary of Agriculture.

growing variety. Planted in this way, the swiftly growing trees act as nurses for the slowly growing trees. Planted thus, black walnut, instead of putting on a scrubby growth and looking like gigantic quince trees when they have reached twenty years of age, run up towards the sun for

light and make good trunks of twenty feet in length. This wood is valuable, and trees thus planted are grown with relative celerity. At Arbor Lodge I have between 100 and 200 walnuts thus treated, which were put into the gronud in the autumn of 1865, and if you could see and measure them, it would be a work of supererogation for me to make further argument in favor of this system of planting.

To grow either deciduous trees or any variety of conifers on these plains with any degree of success, it is necessary



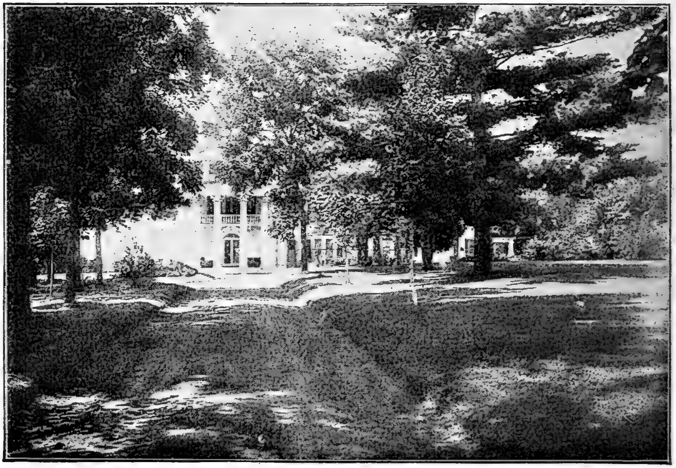
A PRAIRIE PARK.

Portion of Arbor Lodge, showing result of tree planting in Nebraska.

to plant them close together. All great forests, whence have come the best timber that man has ever used for building and cabinet woods, have been dense. The vast pineries of the Northwest were so closely planted by nature that it was impossible for a horseman to ride through many

of them because of the interweaving branches. To successfully grow trees like those the forests produced, we must endeavor to create forestal conditions.

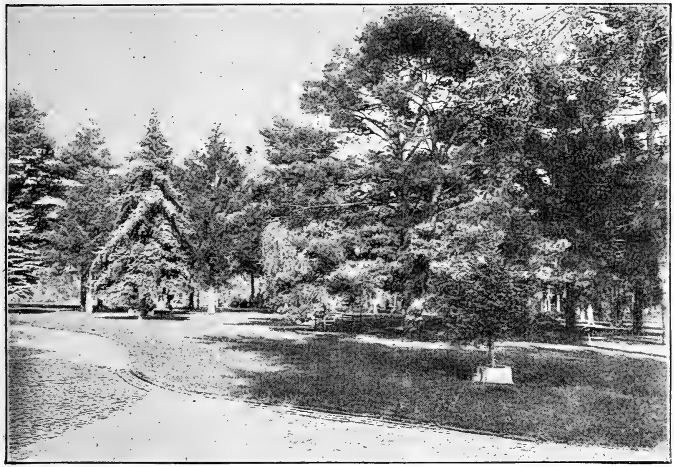
In 1892 I planted 10,000 white pines, purchased of Robert Douglas' Sons at Waukegan, Ill. They were two years old and averaged perhaps a foot to 14 inches in height. They were planted in rows 4 feet apart, and the trees were



ARBOR LODGE.
Home of the late J. Sterling Morton, at Nebraska City.

4 feet from each other in the rows. They were cultivated as corn is cultivated, the furrows going first east and west and then north and south. They have made a remarkably fine growth, both as to height and circumference. Many of them are from four to five inches in diameter and from 18 to 20 feet in height. It is with difficulty that a man can walk among them, and last summer when the drought and

hot winds were doing their worst to smother and parch out vegetation in this section of the country, those pines showed no indication of distress. Going in among them and stooping down, and looking under their lower limbs, one could not see a single particle of vegetable growth aside from the trees. The ground was thoroughly mulched with the needles which had fallen from them, and blanketed the



ARBOR LODGE TREES.

Part of the evergreen grove set by the hands of the late J. Sterling Morton.

earth, so to speak, with the mold which they had created. Removing this carpet of needles one could find moist, cool soil at all times. The conditions about the roots of these trees were such as their ancestors found in the great pineries of Wisconsin, Minnesota and Michigan.

Many varieties of trees have been condemned as unfit for cultivation in Nebraska, after trying them in isolated

positions, exposed to the hot sun and drying winds from the southwest. Trees are almost as gregarious as human beings. No man or woman could have been perfectly developed, physically, and intellectually, in absolute solitude and without communication or intercourse with other human beings. And just so, no single tree planted out on the hot prairie, exposed to the burning sun all day long, can make as perfect a specimen of its kind as can be grown where trees are clustered together.

Arboriculture is absolutely indispensible to the conservation of other plant life, and even to the existence of animal life on these planis. The independence of the lives of trees and the lives of human beings is constant. If a single summer should be passed without foliage, flower or fruit on the globe, all animal existence would cease.

Your great work in soil culture is thoroughly appreciated by every thinking citizen of Nebraska. Your intelligent efforts to benefit the agriculture and horticulture of this state are of greater value to your race and to those who come after you than all the efforts of all the members of congress who have ever represented this commonwealth at Washington. It is a gratification to realize that soil culture and arboriculture are destined, without asking an appropriation from the general government, to revolutionize the climatic and productive conditions of the state of Nebraska. Just as plants need light and as potato sprouts in dark cellars seek the windows and doors where the sun's rays occasionally stream in, so all the people of the prairie states need the illuminating practicalities of your researches and experiments in soil cullture, which illustrate the method of insuring crops by intelligent tillage against destruction by drouths.

J. STERLING MORTON.

ARBOR LODGE, Jan. 18th, 1902.

CHAPTER XXIX.

SOIL MULCH OR DUST BLANKET.

As the interest develops in Scientific Soil Culture there are frequent instances where the innocent are misled in unintentional ways. Among the more common is the reference to the name applied to the loose soil established by the cultivator or harrow over the tilled fields. It is very important that this question be fully understood, for much difficulty and trouble may be avoided thereby.

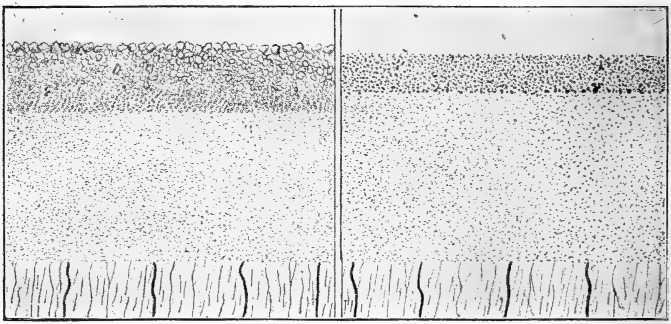
DUST BLANKET.

The name Dust Blanket is an old one and is today very commonly used, especially by the older writers, and as a rule is taken by the farmer to mean literally what it says, dust. The dust blanket in the older and more humid sections of the east where the name originated, was considered by many to be necessary for the best protection of moisture. This, however, has been found to be an error in the more arid sections where the atmosphere is so much dryer. It also was found to be the wrong idea by Prof. King in his very elaborate experiments at the Wisconsin Experiment Station during the early nineties. In the following, quoted from his book, "The Soil," on page 195, he refers to the comparative effectiveness of a mulch of coarse quartz sand that would pass a screen of 20 meshes to the inch, but was retained by one of 40 meshes as compared with pulverized air dried clay of equal thickness. It was found that the evaporation from the soil with dust mulch

prepared from pulverized clay was three and a half times as great as from the soil with the coarse sand mulch.

The conclusions of Prof. King after these experiments have been fully corroborated by all of our observations, there is no result without a cause and a theory can never be accepted as a fact until the cause is fully understood.

Under the head of capillary attraction we have learned that moistures moves very much faster through small pores in the soil than large ones, while it is true that soil abso-

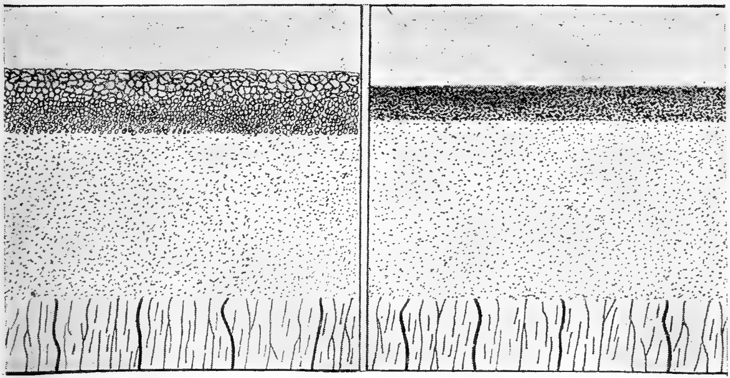


A. B.

Cut No. 22. Soil Mulch and Dust Blanket before rain. (a) Soil Mulch; (b) Dust Blanket.

lutely void of moisture is minus any capillary attraction yet, when the rays of the sun in a mid-July day pierces the soil's surface the dry dust soon becomes so very warm or hot that a vapor begins to rise from the surface of the moist soil below and soon the lower particles of the dust blanket become slightly moistened; then other particles still above, while the lower ones become slightly more moist until connection is sufficient to lift the moisture on up to the surface where it is lost.

The dust blanket is also very objectionable in the early spring, as a warranty deed or a patent from Uncle Sam will not hold it when the strong March winds reach after it. This difficulty, however, is not true in all the semi-arid sections, especially on the Pacific Coast, but is



A. B.

Cut No. 23. Soil Mulch and Dust Blanket after rain. (a) Soil Mulch. (b) Dnst Blanket.

very serious in other localities that are more subject to high spring winds.

The dust blanket is also objectionable wherever heavy rains are liable to occur, more especially in sections where the soils are of a very fine texture. The tendency of a sudden heavy rain falling upon a dust blanket or mulch is to dissolve and run the mulch together, leaving it very hard and compact on the surface. If the sun can reach the surface a very dense crust is quickly formed and if not worked very quickly it will soon be so hard that the common harrow or weeder will not touch it.

SOIL MULCH.

Soil mulch is the true name for the loose soil on surface intended to conserve moisture below, and this mulch should be composed of lumps of soil ranging from the size of a pin head to that of a walnut. To secure such a mulch may seem difficult, but it is not if the soil is cultivated or harrowed when moist, not wet, not dry. When loosened up under this condition the soil readily separates the same as when plowed in ideal condition. Careful notation will disclose the fact that the soil under this condition takes a granular form. The sun soon dries these granules or lumps and no blowing will be noted whatever.

A soil mulch composed of these minute and larger lumps will hold the moisture below without loss very much longer and very much more effectively than the dust blanket.

CHAPTER XXX.

GETTING MOST OUT OF THE FARM.

There is much loss to farming operations, and it is a matter of common knowledge that the great majority of farmers fall short of achieving their best because of the imperfection of their work. There are so many ways that loss can come to the farmer that this is not surprising. It may come through indolence or the inability to do that which is nesessary. Farming is hard work when science is not recognized. It may come through sheer waste, for there is no other place where waste is so easy and so constant unless guarded against. It too frequently comes because of wrong methods, or doing the wrong thing, or trying too many experiments, or because the farmer disposes of his raw materials, and only half completes the work that is his by right.

That there is a right way and a wrong way for nearly everything will not be disputed. Familiar illustrations are found on every hand. The housewife who combines skill and intelligence with her work prepares the bread, and after working, and mixing, and baking, she produces the finest loaf possible. Another with the same materials, and doing perhaps as much work, but in a different way, gets bread unfit for the table. And so it is with nearly everything.

In agriculture it is necessary that the farmer, if he is to keep abreast of the times, if he is to compete with others, if he is to get the most out of his farming operations and

realize what he should, must put his head to work and inform himself as to the correct lines to follow that he may be most successful. He must learn how to handle the soil that he will haye it at his command the largest amount of available soil fertility, and he must know how to use this. But he must go further and make a study of the question how to get the greatest benefit from his crops by diversification of his industry and by completing the processes.

Diversified farming is a subject to which too little attention is given by the average farmer. He imagines it is some fad or tomfoolery and that it is best confined to the books. But it is a reality. It shows results, and that is the important thing.

The farmer is by nature and training conservative. He has done well; he cannot very well realize how much better he might have done, or what is possible for him in the future. He does not comprehend, except in rare instances, the vast difference in final profits between doing things by strictly scientific methods and doing the same things by the common go-lucky way.

It is not sufficient that the farmer find out how to grow the largest crops and get tons or bushels as his portion; he must know what further he can do with his grain and hay and fodder to make the end most desirable. Diversified or mixed farming shows the way. Grain raising to the exclusion of all else is not wise. It is wasteful to the land, and wasteful to the crop itself. By raising all kinds of crops better results are obtained.

And in the matter of preventing waste, it is essential that live stock be added to the farm. Cattle and hogs, and perhaps sheep and poultry, are necessary. Right there the farmer becomes in part a manufacturer. The

conversion of the corn and oats and hay into meat, butter, cheese, etc., is the aim of farming operations in general. The grain must finally be fit for human food in some form. Raising live stock is a part of the process of manufacturing good food out of the grain.

Dairying and poultry raising go a long way toward completing the natural processes of the farm. Both are possible in some degree on all farms. Sometimes best results are possible in dairying only where there are many farmers combined to work together, but always there is some advantage in keeping a few animals on the farm. As to breeds, feeding and care of live stock that is another question—one so broad that it should be treated in separate volumes—but its relationship to other farm operations is easily understood.

It has been declared with much positiveness that the waste on an average farm represents a value greater than the average profit of farms. If so, then farmers have not done as well as those who have devoted themselves to commercial pursuits. The expense of operation of the great packing plants, so it is stated, is paid in full by the receipts from that which formerly went as waste in the processes of meat marketing. A good deal of the same kind of economy is possible on the farm.

In the matter of preventing waste on the farm nothing is quite equal to cattle and hogs. Between them they glean all that is valuable, But in addition they retain on the farm that which is valuable to soil and which may be returned from time to time in the form of the barnyard manures which are essential to the best farming operations. The application of barnyard manures to the land will go far toward, and is one of the requisites in maintaining the soil fertility and offsetting the evil effects of drouth.

The proper diversification of farming operations is a fit subject for much study by every intelligent farmer. It has relation to all his work. It goes to the point of conserving soil elements and building up the soil by development of the necessary humus, and it has relation to waste and to partial manufacture as a part of farm work. The diversification may come in a score of ways. It is not best to carry it too far or to try all ways at once; but careful study of the subject in connection with the local conditions and opportunities will point the right way. It is at least quite proper to make a specialty of some one thing.

In a large sense the science of proper culture of the soil so as to make its properties available for the best results is only one branch of the larger subject of properly mixing the farm operations so as to get the most out of the soil.

CHAPTER XXXI.

PRACTICAL RESULTS.

What has actually been done to demonstrate that scientific soil culture is practical and that good results follow?

The question is a proper one. The careful reader of this manual will hardly need to ask the question, for scattered all through it is given many illustrations of what has been done, and many reports are made of specific results attained under the system. But at the risk of doing that which is needless, we desire here to present just a few facts showing some of the things done, so that the inquirer may have them all in one place to better consider them.

This work has been done by conducting experiments at a number of places, which are mentioned in the Manual but we will here confine our record to a few where the most careful work was done.

First, was the accomplishment at the Pomeroy model farm at Hill City, Kansas, far out toward the Colorado line. This is a locality which has been regarded by many as about as unfavorable as it was possible to find. The author of the Manual conducted for Hon. James P. Pomeroy a model farm, of Colorado Springs, and a great deal of what has been learned came out of that farm. It was started in 1900. As illustrating results, it can be said that one field that had been farmed for fourteen years, and never but one crop cut in that time, was summer tilled in 1900, and yielded 42½ bushels of wheat in 1901; was summer tilled

again in 1902, and cropped in 1903-4-5-6, averaging in the four seasons fully 40 bushels per acre. The last crop, that in 1906, a very good year, and the yield was the largest ever grown on the land.

THE BURLINGTON FARM.

Second, and more important, because conducted with even greater care, was the results from the Burlington model farm. This is a tract at Holdrege, Nebraska. In 1905, for instance, wheat to the amount of 54½ bushels and testing 63 pounds, was secured from summer tilled lands, while other lands well handled on the same farm but not summer tilled, only gave 32 bushels testing 60 pounds. In 1906 what on summer tilled ground gave 51½ bushels testing 64 pounds. Wheat as a second crop on land summer tilled in 1904, which yielded 54½ bushels in 1905, yielded in 1906 49½ bushels testing 63 pounds. Wheat on land well handled but never summer tilled yielded 28 bushels testing 60½ pounds. This all showed the marked effect of summer tilling on the second year's crops.

Again, it was shown in experiments on a farm in Hitchcock county, Nebraska, in a crop of 1904, what could be accomplished. Here a wheat crop of 41 bushels per acre was obtained on ground properly handled under the Campbell system, when 90 per cent of over 20,000 acres in the same county was a total failure.

At Grainfield, Kansas, in the same year, a yield of 56 bushels per acre was obtained, when many fields around failed entirely because of the drouth in 1903 which continued up till the spring of 1904.

Henry F. Kipp has had success with the Campbell method in Western Nebraska, where in the summer of 1904, he

harvested from 20 acres sown in winter wheat 820 bushels testing 59 pounds, or an average of 41 bushels per acre. This was on land cultivated the previous year, when the nearly eight months of drouth gave a loss of 90 per cent of the wheat in the same neighborhood.

COLORADO RESULTS.

A number of farmers in Eastern Colorado made reports on the results of their 1906 work in following the Campbell method of soil culture for wheat, and here is a brief statement of the same: Charles Butler, Calhan, 36 acres, 31

Sorghum by Thorough Cultivation on sod breaking in Eastern Colorado.

bushels; W. Syes, Calhan, 20 acres, 32 bushels; E. Loring, Yuma, 40 acres, 36 bushels; George Owens, Longmont, 72 acres, 39 bushels; E. A. Mead, Ault, 40 acres, 48 bushels; E. P. House, Greeley, 53 bushels; John F. Wright, Longmont, 25 acres, 53 bushels; William Callaway, Wray, 20

acres, 62 bushels; Lee K. Klein, Loveland, 40 acres, 65 bushels; In this same vicinity the same season Bergstron Bros., of Longmont, got 80 bushels of barley; A. Mead, of Ault, got 75 bushels barley; and L. L. Mulligan, of Longmont, got 75 bushels of barley. The results show that these farmers did not follow the system closely or perfectly but they did get results just in proportion to the fidelity with which they followed out the system.

Near Limon, Col. W. S, Pershing got over 300 bushels per acre of turnips which he sold for 75 cents per hundred weight.

In raising corn Charles H. Lee, 40 feet from water, raised 30 acres of corn which gave 50 bushels to the acre, and on watermelons he realized $150 an acre. Henry Swan 50 feet from sheet water, raised on 40 acres 30 bushels of macaroni wheat per acre, and on 50 acres of corn he got 50 bushels per acre. B. Rice, 40 feet to water, got 40 bushels per acre of corn from a 30-acre tract.

Joseph Emmal, who lives near Ramah, Col., following the Campbell sytem, reported an average of 120 bushels of potatoes; and C. F. Butler, near the same place reports that for five years he has averaged 130 bushels of potatoes per acre.

E. R. Parsons, on an orchard near Parker, Col., made a net profit of $1,345 from 1,000 cherry trees, 500 plum trees, 200 apple trees and 1,400 currant bushes. All were cared for under the soil culture methods.

On the grounds of the State Soldiers' Home at Lisbon, N. D., in 1897, on a tract cultivated for two years under the Campbell method the phenomenal yield of 23 tons of sugar beets per acre was obtained.

As to what the use of the system has accomplished in four counties of Colorado alone, where the farmers have made more general use of the system than elsewhere, the

land department of the Union Pacific makes the following estimate of the wheat and corn acreage and crops in three counties, the counties mentioned being Adams, Arapahoe, Lincoln and Cheyenne.:

	Wheat.		Corn.	
Year.	Acreage.	Bushels.	Acreage.	Bushels.
1905........	2,000	30,000	5,000	100,000
1906........	12,000	180,000	12,000	300,000
1907........	35,000	525,000	30,000	750,000

On the ranch of Kilpatrick Bros., in Chase County, Neb., in 1904, a wheat crop was grown with 30 bushels to the acre, whereas all round, because of a seven months' drouth, there was total failure of the crop.

On the Burlington farm in Nebraska, 228 acres under cultivation were handled in 1904 and two subsequent years by two men and nine horses, except harvest time; and in 1905 the net profit on the farm was over \$4,000 or \$11.76 per acre on the entire acreage of 340 acres in crops, meadow and pasture.

We give these various specific reports only as samples of what has been done; but results have been achieved all over the states of the semi-arid region quite as striking.

ONE EXAMPLE.

J. D. Clarkson, writing from Greenfield, Kan., tells of the result of work being done there as follows:

"I was out east of this town looking over some wheat fields and am sending you two samples of wheat as found growing in the same fields not ten feet apart. One of them was growing on ground cultivated by the Campbell system for two years. This is the second crop. It yielded 34 bushels to the acre the first crop. The other sample was taken from land not over ten feet away that has been cultivated by the old method of disking the wheat in the

stalk ground. An exaination of the sample that was taken from the land under the Campbell culture shows a bunch of roots forty in number, ranging from two to four inches in length, each of which is strong and vigorous. From this bunch of roots have sprung eight stalks now ranging from nine to twelve inches in length. This all comes from one grain of wheat that may be seen just in the center of the bunch of roots. On the land that was disked in among the corn stalks I had to take five bunches of roots to get eight stalks, and they did not average more than one-half the size or length of the others, and the roots in the five bunches are not half as much as the others in bulk or length. These two samples of growing wheat, taken as they were from land otherwise just alike except in the manner of cultivation and seeded about the same time, is a glaring example of the value of your experiments and researches in the interests of the farmmers in the semi-arid belt, and it would be to the financial interest of these prople if some means could be devised whereby results of your years of experience and experiments could be given much wider circulation, especially for those who are just coming into this section."

A KANSAS EXPERIENCE.

The following letter written by J. B. Beal, chief land examiner of the Union Pacific land department, to Land Commissioner Houtz, at Omaha, Aug. 1, 1904, from Grainfield, Kas., tells an interesting story of results:

"You wrote me on the 6th of May in answer to a letter I wrote you about the field of wheat east of Grainfield that we looked at when you were here, I thought I would wait until the wheat was harvested and thrashed and then give you a full synopsis of the matter. All of this has taken

place. I will commence at the beginning. This ground was plowed good probably six inches deep the first part of June, 1903; it was sub-packed and harrowed as soon as the plowing was completed, then after each rain, I think a day after, the ground was harrowed over and the crust that would have formed on the ground when it commenced to dry up was pulverized and made fine. This tract of land was harrowed I think seven times between the time of packing after plowing in June and the time of seeding, which was the 19th, 20th and 21st days of September, and there was nothing more done to this field of wheat until the harvesting commenced. The cost of the work, and it was all hired done, including the purchase of the seed wheat, was $3.25 per acre; this wheat made a fairly good growth last fall and as soon as the warm days commenced to come this spring this wheat began to grow and you remember how it looked the night we walked over it, and this was long before we had our first spring rain. It kept on growing until it was a good height and completely covered the ground before we had our first rain, looking all the time as fresh as a rose. The people were watching this wheat field, and as no other wheat in the country was growing at all, they concluded one evening they would fix up a test auger and go over there and test the depth of moisture in the ground. They found it upon their investigation nice and moist five feet down, and of course this is the sequel of the whole matter. All of this moisture fell on the ground last summer after the plowing was done and retained there by this system of harrowing the ground after each rain, keeping the ground fine and loose on top.

"We find by the Campbell System that we can as well keep the moisture in the ground as to put it in a jug and put in a cork. This wheat field has been looked at by

many people this summer. The ground has been carefully measured and found to contain a trifle less than 38 acres.

"It took five pounds of twine to bind each acre, and with the black rust that struck the wheat, the same as all other fields in this country, this wheat yielded a little over 35 bushels per acre and weighed 60 pounds per bushel. The people that know most about wheat in this country say that the rust damaged this field of wheat not less than 20 bushels per acre, and my honest belief that if the rust had not affected it it would have made 60 bushels per acre.

"The wheat sold for $22.50 per acre, less the cost of planting it and placing it upon the market, which was $6.50 per acre, leaving a net profit of $16.00 per acre. I think this a fair margin for $5.00 land."

CHAPTER XXXII.

WINTER KILLING OF AUTUMN SOWN GRAIN.

The question of winter killing of autumn sown grain in the semi-arid belt is one that called forth much discussion along in the nineties, but of recent years we hear but little except an occasional comment in a severe cold period during the winter months, when the fields are bare. This fact is largely due to better fitting of the soil bed by the farmers generally.

Few people realize just why autumn sown grain winter kills. Years of careful observation have proven conclusively that it is invariably due to a loose seed and root bed and little moisture. We have never seen any apparent signs of winter killing on any part of a field that had been summer tilled except where water had stood for some length of time and frozen.

In the autum of 1898 a great portion of Kansas and Nebraska had very little rain, in short but little rain fell after the middle of August, except in the extreme eastern part of the two states, therefore a large amount of fall wheat was sown in soil plowed and fitted rather dry. Rain was sufficient to germinate most fields of wheat, but the winter was open with frequent freezes, and when spring came much wheat was found to be dead. The writer was asked to investigate and gave much time to the question. Over a considerable scope of the country we found the following facts and conditions to be uniformly true.

Through the major part of all fields, the wheat was

badly damaged. Wherever we noted a horse foot track the wheat in or at the edge was invariably green. Where we found fields plowed round the field, at the corners where the horses had tramped the portion in turning, we also found green wheat. This was especially true in one field in Northwest Kansas, where the farmer had harrowed his field thoroughly after plowing as above mentioned and before seeding. Other marked contrasts were shown in the dead furrows and the back furrows. In the latter the wheat was almost invariably found dead entirely, while along the edge of the former we found good stands of green wheat. These observations together with many others led us to one conclusion, viz., that winter killing of all autumn sown grain would never be known, if the following principles were carefully observed:

1. Conservation of soil moisture.
2. Plowing of fields only when moist.
3. The use of the sub-surface packer well weighted at the proper time.

It is exceedingly difficult to put too much stress upon these three requisites, especially is it true with reference to the packer; its work is most vital for the development and support of strong and healthy plants.

We would also call attention to some very strong corroborating evidence in the quotation from Bulletin No. 52, issued by the Agricultural Experimental Station of Illinois in 1898 referred to at length under tree growing, the sum of which was that fruit trees winter killed frequently in early fruit growing in Illinois, and it was finally agreed that soil and climatic conditions were not favorable for fruit growing, especially apples. After the Agricultural College began to take notes it soon became evident that the trouble all came from trees going into the winter with

little or no moisture about the roots, since which time there has been no trouble whatever, and the same sections have proven to be great apple producing localities, by simply handling the soil just a little differently.

Few farmers in the central west today would think of handling their soil as was commonly done only eight or ten years ago, and yet they are only just beginning to grasp the fundamental principles, all of which mean dollars, happiness and greater prosperity to them.

CHAPTER XXXIII.

STOOLING OF GRAIN.

The real cause of small grain stooling is not a question well understood by the average tiller of the soil, and yet it is a subject that if well understood would pave the way to the comprehension of other even more puzzling and yet most important subjects. The simple fact that the farmer has not understood this question has led him to do things that has cost him money as well as bring an actual detriment to his crop. To understand these principles is to explain and make clear why the farmer should be so very careful to carry out many of the principles laid down under the chapters on Plowing, Sub-Packing and Summer Culture.

To more clearly explain this phenomenon we call your attention to Cut No. 24, where we show the two conditions, one of which promotes stooling the other does not. At the left is the more common condition of the soil in the average western field. This represents soil that has not been packed and has been plowed when in fair conditiou and harrowed. The root system here is not large because soil of this nature does not carry a large amount of moisture, on the other hand it carries large quantities of air. This unbalanced condition brings about slow chemical action which liberates small quantities of plant elements or fertility, consequently the development of roots is but little in excess of what the first and original main stalk can take care of, consequently little or no stooling has taken place.

Theory among many of the early farmers had it that a period of cool days was necessary for stooling, therefore when this period came it was as a rule hailed with joy. This is what we should call stooling under forced conditions, such as would not result in well filled heads from the increased stools.

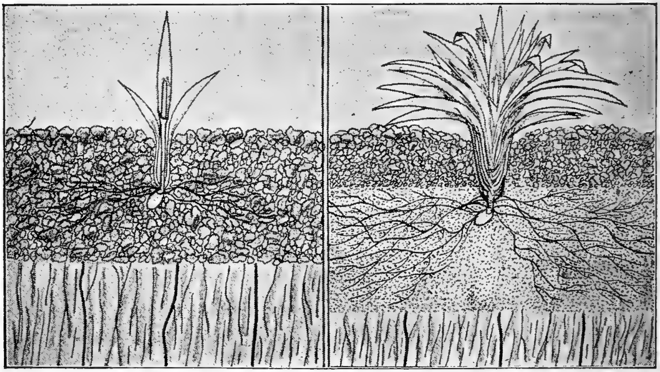
It is true that a cool period after the soil has warmed up in the spring and growth of the young plant commenced will cause stooling, but why? Because the rootlets are gathering in the moisture laden with plant elements and starting it on its way to light and sunshine, when the atmosphere cools to that degree that there is no evaporation for the leaf, the movement up the main stalk ceases.

CAUSE OF STOOLING.

The moisture and plant elements being gathered in by the little hair roots or feeders must materialize somewhere, consequetnly the additional stooling or increased number of suckers or stalks. Now these little new shoots soon become full fledged stalks. The consequence is an increased leaf surface, and when the clear, warm, sunny weather comes on and the leaves are fanned by the warm southern breezes evaporation from the leaf surface is greatly increased, and each warm period as the leaves increase in size and number brings a greater demand on the roots for moisture. Under the soil conditions shown on the left, the time is sure to come when the requisite amount of moisture cannot be supplied, and when this time comes we have a condition quite similar to the oil lamp when the oil has been all taken out of the bowl by the burning blaze at the top of the wick. Steadily the soil becomes drier like the wick and finally these stools begin to die off. When this period is reached the real damage to the final crop is

measured largely by the stage of growth of the plant. If at the beginning of the farming point the head in the original or parent stalk will be smaller; if at the kernel forming period, the less kernel, etc.

The point we wish to convey is the fact that coarse, loose soils as shown in the cut at the left will not permit



A. B.

Cut No. 24. Growth and stooling of grain. (a) Growth in loose unpacked soil. (b) Growth and stooling of wheat in ideal soil conditions.

of a perfect root system, and will not carry to exceed one-fifth to one -tenth the amount of moisture (see cut No. 10); also that moisture will not move by capillary attraction more than one-fourth to one-eighth as fast in such soil consequently crops under this most common condition in the past, during a prolonged drouth, had to suffer severely or perish entirely.

THE SCIENTIFIC CONDITION.

At the right end of cut No. 24 we have the ideal condition. As shown in cut No. 16 the lower portion of the fur-

row has been made fine and firm. The seed has been deposited in the little V-shaped crevice where germination is rapid and the little rootlets almost immediately begin to meander about in all directions, sending out numerous little feeders to gather in moisture and plant elements. By this rapid development of roots, each doing its part as nature intended, the moisture and plant elements are gathered in so rapidly that the little lone stalk cannot take care of it all. This plant element must be utilized in some manner and out comes another tiny stalk, then another, and so nature's desire for life and growth goes on in its active work until ten, twenty, fifty and we have seen even one hundred and two perfect stalks with wheat bearing heads grown from one kernel.

This very marked stooling will take place very largely in proportion to the physical condition of the soil and the amount of available fertility. For example a piece of sand loam prairie with a clay sub-soil such as is found, as a rule, in the great semi-arid belt that has been cropped one or more times, then summer tilled carefully as explained in Chapters 8, 9, and 10, you will have a condition that will not permit of sowing over twenty pounds of winter wheat or twenty-five pounds of spring wheat, and if the work has been well done and in the more arid portion of the semi-arid sections, not more than three-fourths of the above amount should be shown.

Stools developed under these conditions are very much more likely to carry through and mature.

CHAPTER XXXIV.

QUANTITY OF SEED.

What the necessary amount of seed per acre is, is a question somewhat complex, as there are many little details some of which have much to do with the quantity of seed and the final crop result. Therefore, we find it entirely out of the question to outline imperative rules for the real or necessary quantity of seed.

We well remember a book published about twenty-five years ago which had a table giving the required amount of seed for the different farm crops. As we now understand soil physics, soil fertility and the moisture question, this table seems not only very inconsistent, but ridiculous. For example it says "75 to 90 pounds of winter wheat per acre on good rich soil." To cover practically what was meant by the language we would now say that on good soil scientifically fitted from 15 to 20 pounds of winter wheat, and if more was sown, the chances would be very much in favor of less yield of grain and a poorer quality

On the Burlington Model Farm in the autumn of 1904 a piece of summer tilled land was by mistake seeded with thirty pounds of seed, and the result was straw and heads enough for seventy bushels per acre, but it was so thick that the straw became weak and more or less of the entire field went down. The yield was only 46½ bushels per acre, the grain testing only 58 pounds. The stubble was so thick, long and more or less matted that we were obliged to burn it off to plow. This same field was seeded again

to wheat in the autumn of 1905, and anticipating less available fertility we sowed twenty-two pounds of seed and the 1906 yield was 49½ bushels per acre, testing 63 pounds per bushel. Several similar instances have been observed with like results, showing conclusively that we must gauge the quantity of all kinds of seeds per acre by the physical condition of the soil. The more ideally perfect the soil is fitted, the greater is the amount of available fertility, consequently the less seed is required by nature for the best results. As a rule summer tilled fields that are scientifically handled require about one-third the amount of wheat, oats or barley that has been commonly sowed by the farmer, but careful observation in testing fields only can give the farmer the correct idea as to the proper quantity for certain conditions.

It should be borne in mind that with coarse plump seed slightly more is required; on the other hand fine, somewhat shrunken seeds with a healthy germ require less; also that early seeding requires slightly less seed than late planting. Keep in mind that the proper quantity of seed with thoroughly fitted fields gives the highest yield, that above or below this ideal quantity will diminish the yield. The rule today is too much seed per acre; the quantity as well as the quality is frequently less from over seeding.

For well fitted summer tilled fields the following quantity of good seeds is most desirable when the seeding is done sufficiently early: Winter wheat, 18 to 20 pounds; spring wheat, 22 to 25 pounds; oats, 20 to 25 pounds; barley, 35 to 40 pounds per acre.

Corn to do best in the more arid sections should never carry more than two kernels to the hill. Potatoes should be planted early with from one-fourth to one-third less seed than is commonly planted in the more humid sections.

The main points to keep in mind are: First and above all things, as nearly as may be possible a perfect physical condition of the soil backed by ample stored water below; the good seed carefully selected, followed by good judgment at seed time to see that the quantity of seed conforms to soil conditions, the careful after culture together with not only an ambition but an effort each season to excell the previous crop. Remember that the average crop is not one-third of the possible yield of our soils.

CHAPTER XXXV.

THE INEVITABLE DRY SEASONS.

The seasons change and the favors of nature are given or withheld by the operation of laws or influences of which we know little. No man can know just when the storm will come or when the drouth will follow. But we do know that, in a general way, long periods of abundance of rain are likely to be followed by periods of drouth, and for this we must always be prepared.

We clip a fugative item from the daily newspapers in March, 1907, as below, in which Prof. Willis L. Moore, chief of the United States weather bureau at Washington, is quoted as giving warning of a drouth in the western country. We give it not so much that this prediction has value or causes surprise, but for reasons which are indicated later. The item is:

"Prof. Moore predicts that the country is due for a long period of drouth. The present long period of abundant rainfall over the great cereal plains, about six years, is the longest of which the weather bureau has any records. Prof. Moore is certain that there will be a shortage in rainfall soon equal to amount to the excess during the last six years. This is based on the records of the bureau, which show that the average rainfall during the first ten years of a period of thirty, forty, or fifty years is precisely the same as the average of the last ten. Many persons write to the bureau, saying that they have been advised to buy land in a region formerly classed as arid. It is offered for sale to

them on the ground that there has been a permanent change in the climate. Invariable Prof. Moore answers that the climate has not changed. Prof. Moore points out that the country does not need as much rain as it did formerly to make the land productive. The virgin soil is being broken up and the trees are being planted. While this does not increase the rainfall, as is sometimes stated, it makes the same amount more efficient and more profitable, because the soil is broken up and there will not be so much evaporation, the ground absorbing it more thoroughly."

The warning should be taken to heart by everyone, not with fear and forebodings, but with redoubled effort to solve and solve correctly and finally the problem of how to meet just such conditions as are predicted without danger of crop losses.

It is worth while to point out that if there are persons who are urging others to begin farming in the semi-arid or arid regions on the claim of there having been any permanent change in the climate they are the worst possible enemies of those whom they would dupe, as well as of the country they seek to populate. There is no reason to believe there will be any material difference between the climate of the Twentieth century and that of the Nineteenth.

But Prof. Moore does recognize, as many others have that conditions are changing in the semi-arid country and that better results are being obtained. Naturally he looks about for a cause and an explanation. He gives that which comes most readily to hand. It is true there is no increase in rainfall—averaging up one year with another—and it is true there is an increase of moisture available for the use of the plants. It is hardly fair, however, to

attribute this merely to the fact that "the soil is broken up," unless it is intended by that phrase to include a good deal more, and to convey the idea that not only is the soil broken up, but that the farmers have been intelligently applying improved methods of cultivation with special view to meeting the adverse conditions which they find all about them. With this modification the hint of explanation, which may not be exactly as Prof. Moore himself would put it, is all right.

That the semi-arid regions are better prepared now to fight the drouth and to stand independent of the varying fortunes of the weather, is certainly true. Yet much more can and must be done in the way of spreading the knowledge among the new farmers of the new west.

CHAPTER XXXVI.

THE DOMAIN OF SOIL CULTURE.

Who shall bound the domain in which scientific soil culture is destined to be in fact a redeemer? It is a new thing, but many there are who inquire anxiously as to its limits. But no man can yet tell. It surely is far reaching

One thing is certain, scientific soil culture is not a system adapted solely to farming in the dry regions, but it is a system useful also to the farmer who may have in most years an abundance of water. Let it be remembered, and this is something within the knowledge of all, that there are very few places anywhere on the globe entirely free from the danger of disaster to crops by reason of waste of the water. The farmer, no matter where he lives, is indeed rare who has never seen his crops wither and decline during a drouthy period for want of perhaps a small amount of moisture at the critical period of growth.

But there are regions where it is indispensible, where irrigation is impossible, and the plan of adopting desert plants has not been made a success. This area is large.

Like other useful things in the world, scientific soil culture is a child of necessity. The system was developed in adversity. Failure was its inspiration. There is an irregular and variable line running through the Dakotas, Nebraska, Kansas, Oklahoma and Texas, which has long been supposed to mark the extreme limit of profitable soil tillage for ordinary crops. It was on the border line of the farming regions, right where they merge into the broad acres

of grazing land, that this system of eliminating the imaginary boundary line was developed under our own guidance. Under the old system there was the long series of alternating successes and failures, resulting in an impoverished land and heart broken men and women, for the failures were more numerous than the successes. Here was the birth of scientific soil culture, and here it has had its first and greatest victories.

But a great deal has actually been done in at least a dozen good states. In eastern Colorado splendid results have been achieved by application of the principles, often imperfectly it is true, yet sufficient to produce good results. In western Kansas and western Nebraska the triumphs have been great. Something has been accomplished in northern Texas, and in Oklahoma and New Mexico near by. In Wyoming and in Montana, in many rich valleys and uplands, the good work is going on. In all these states individual experimenters are accomplishing good results. These are mostly homesteaders and those who have purchased railroad lands. Thousands of our 1902 and 1905 manuals have found their way into the hands of men who are tilling the soil in these states. They make use of the ideas they have gathered there, and in due time they will come into the full fruition of their labor and studies.

But the call is also for more detailed information and from further west. Out on the plains of eastern Oregon enterprising and courageous men have taken up the system and are working it out with results that are astonishing to their neighbors. In Washington and California interest is being taken in the subject. We have lectured in many states and explained the system and are having calls to go to many of these states for further work.

But the system is of value also in the more favored

regions of the Mississippi valley and along the coasts of lakes and oceans where there is abundance of water, but where distribution is not always what it should be. Farmers in these regions are making use of the principles enunciated to enable them the better to increase their yields and to make doubly sure of good crops.

Within the past year we have been visited by men from South Africa, with a view to having our system tried there. Letters and inquiries have come from Porto Rico, Australia, Mexico, Canada and elsewhere, indicating that there is demand for knowledge concerning the system all over the world.

The soil culture empire has no limits. The system is useful on every farm. It reaches over oceans and mountains. Over vast areas the principles are triumphing over the perverseness of nature. And some day this soil culture empire will be the garden spot of the earth.

CHAPTER XXXVII.

PROGRESS IN AGRICULTURAL SCIENCE.

A great deal is being written for the books, magazines and newspapers about the wonderful things that are being done in all industrial lines for the advancement of the human race. It is era of achievement. Men do things. And as a result the sum total of human happiness is promoted with much rapidity.

We all feel that the natural trend of things in the opening decade indicates that the Twentieth century is to mark an advancement in all material things that go to give comfort to mankind far in advance of the splendid record of the Nineteenth or any previous century. The passion is for progress, for the new things, for the better things, for the more perfect organization and accomplishment.

Yet it is all too true that man is naturally conservative and is prone to cling tenaciously to the good old things. He changes only under stress of necessity. That which is new must demonstrate its right to existence. It is everlastingly true now as it has always been in the past that conservatism stands in the way of progress. Inventors and discoverers have had to meet and overcome conservatism with its strong backing of prejudice. One such was compelled to go to prison because he declared his belief that the world was round. Another struggled for years to get a hearing in his project of demonstrating that he could cross the ocean and reach the Indies by apparently going away from them. An inventor who devised a ma-

chine to sew mechanically was denounced as having sought to take from the seamstresses their means of earning a living. Wise railroad owners laughed at the young man who first proposed a plan for stopping railroad trains with air. Men who have taken the advance step in discovery or invention, in all science and knowledge, have won their way over ignorance and prejudice. Sometimes it has been necessary to overcome the inertia of error as it lies entrenched behind years of wrong teaching. Of course the truth prevails in the end; but to very many of those to whom it has been given to be leaders in special lines it has seemed like long waiting for the victory.

If there is progress in industry generally there is also progress in all forms of industry that relate to farming. And if this progress in most things is accomplished spite of prejudice it holds true as to agriculture. Scientific culture of the soil is a step forward; but it has had to make its opposition. It has proved its worth on the great prairies of the west that have been given a bad name by the early travelers and investigators. They got a wrong idea and passed it on to others. From their ox-train wagons they looked out upon what seemed to them a dreary waste of more than half desert land. They had left the trees and the wood-bordered meadows behind, and they sent back word that between the valleys and the mountains was a trackless plain fit only for wild and roving bands of buffalos. It was advertised that these vast regions were uninhabitable.

But later came the trans-continental railroads to connect the oceans. Travelers whose investigations were made from the windows of swiftly speeding cars told only of the sandy plains. They did not stop to consider that perhaps here was a country where Nature had left it for man to solve a few problems by study and application. It would

never do to make the whole face of the earth a Garden of Eden, where man had only to gather the fruit and eat.

And so to the natural conservatism of man in regard to all things was added the wrong teachings as to the character of the vast semi-arid regions, and this in time engendered deep-seated prejudices, which it will take many years to remove. Then, again, there have been years of study of agriculture following the lines of the forefathers, and adapting the study to conditions that generally prevail where agriculture is most favored. Here again is created prejudice against anything new or different.

Scientific soil culture has been under the necessity of making a place for itself despite prejudice. It has been necessary to not only show that this method is right, but also that old methods are wrong.

Agricultural science is making as great progress as any other branch of human activity. The prejudices of the past are being broken down rapidly. Men are thinking about the matter and thinking differently from what they were. One cannot make much progress without getting into a new way of thinking. Scientific soil culture involves this very thing, for he who succeeds at it must do very much original thinking that he may work out the little problems which no man can foresee. If the farmer who approaches the subject in the right spirit becomes filled with the true principle he will invariably reason along the right lines and come out right. Its methods do not involve new machinery, and in some things the methods are but variations of those in common use, but it does involve a new way of thinking, which is the foundation of the science.

So soon as prejudice is wholly put away then will progress in agricultural science be on a par with that in other more advanced lines.

CHAPTER XXXVIII.

CROPS, MARKETS, PRICES.

The farmer not only wants big crops but it is his desire to get the best price for the same. That which the crop brings, directly or indirectly, is the prime object to be ever kept in mind.

There are a good many elements entering into the price question and men may easily make serious mistakes. Of course there may be at any time in almost any community some advantage gained by taking advantage of temporary or local conditions; but it must be remembered that the price of agricultural products is generally more unchanging through a long series of years than of any other class of commodities. Statistics have been kept by the commercial associations, including the price of agricultural products as well as of other things, and compilation from these shows that the fluctuation in average value of farm products from year to year and from decade to decade has not been great. It is gratifying that there has been a tendency for many years to a slight average increase in value.

The theory that all would be lovely with the farmers if they could only form a trust or combine and artificially limit the production of farm staples so as to force prices up, or to hold grain and produce so that the marketing could be done with special reference to holding up the price, has little to support it. The notion is equally wrong that the farmer who manages to have a good crop when

all his neighbors have none, or that assumes that crop failure somewhere must be necessary to good prices at some other place.

The ideal conditon is that of having good crops every year and in all places. You can gain no permanent and enduring advantage by the misfortune of your neighbors.

What is it that demoralizes prices and brings distress to farming and other industries? Not over-production, but lack of production. The poor crops your neighbor has will cause you to suffer in the end.

The fact of the matter is that we shall never know a time when production will outrun demand and the markets of the world will be glutted. This might happen with one or two things, but not with things in general. More and more it is going to tax the ingenuity of man to provide for his own necessities and desires. The area of land available for agricultural purposes is limited and it will be nearly all made use of in some way in the very near future. The problem must ever be that of how to so increase production that there will be competence for all, then how to distribute this throughout the world.

But under present conditions, with commercial war a perpetual thing, encouraged and guarded and supplied with weapons by our governments, there is a scramble for markets. We of America set out to corral a desirable market for a certain line of goods, especially farm products, and have it well in hand when there comes a season when we cannot supply the demand, as was the case in the early '90's, and immediately others step in and take possession of the field. Then when we are ready to again furnish our former customers with what they want we find that they have made arrangements elsewhere that are satisfactory to them. Right there the evil effect of poor markets is

felt, not by those who lost at once but by all who are engaged in production. A market once lost by demoralization is hard to get back again.

But in another way poor crops in a part of the area of production has an evil effect over all the area. The farmer is himself always a consumer. If he is prosperous he buys things. And as he buys things he helps to keep off the demand for the products of many others in other industries. Thus all become consumers and all propsper together. But with some of the farmers reducing their expenditures because of their temporary misfortunes by decreased yields, the total of demand for all the ordinary things of life is materially reduced.

The true principle for the farmer is to strive to have good average crops and have them steadily all the time, and here it is that scientific soil culture plays its noble part. The greatest thing that is possible for any state or any nation or any section of country is to have assurance of good crops every year. If this is done the price question will soon adjust itself to conditions so that the market problem is less and less one to cause worry to the farmer. If there is a surplus, be it large or small, a place will be found where it will be absorbed properly, and this once established will remain permanently. Everyone will rejoice in the good fortune of his neighbor.

The real problem of prices and markets is that of how to guard against the distressing ups and downs of crop yields incident to the hit and miss style of farming which is partly guess work.

Scientific soil culture gets at the root of the problem. It shows the way. It is directed toward making crops grow where they were not before grown and also, and this is most important of all, toward the making certain of good crop

every year where under the old system crop failures were inevitable at times.

The condition which is desired is one of assurance of good crops, with the consequent assurance of fair and steady prices, and this state of affairs running through a series of years unchanged, not a fluctuating and uncertain condition with an occasional good crop sandwiched in between several poor ones and some failures—and when this condition becomes general, as it will, there will be no more complaint of market demoralization and no desire to combine to limit crop production and exact high prices.

CHAPTER XXXIX.

WORLD WIDE FAME OF THIS WORK.

It is a matter of genuine pride and satisfaction that there has come to be, even though it is after years of waiting, almost world wide recogniton of the truth of what we have been teaching as to the proper method of conducting farm operations on the semi-arid soils. Of course it is a matter which, from our standpoint, cannot be explained, why farmers and students generally have been so slow to see the truth, but we make due allowance for the momentum of centuries of conservatism.

But if recognition of the truth comes apparently very late it seems to be coming with added force and greater meaning. Within recent months we have had evidence of a desire to know more of the system coming from far off lands on the other side of the world, and there is a demand for some information on the subject in many countries. The system of scientific soil culture has forced itself to the attention of many of the best students and writers of the country. In the Century Magazine for July, 1906, there appeared a discussion of the whole subject by John L. Cowan, of Albuquerque, N. M. In the World's Work the same season appeared another similar article by Herbert Quick, the talented writer. William E. Curtis, a famous correspondent writing for the Chicago Record-Herald, told at length in July, 1905, of the work being done by the Campbell method in Kansas and elsewhere. The western newspapers have been filled with information on the sub-

ject. The Northwestern Miller, of Minneapolis, in November, 1906, gave five pages and over to a presentation of facts regarding the system from the pen of Mr. Cowan. Some excerpts from these various articles will show how the world is coming to regard the work.

SALVATION OF THE DRY BELT.

From the article by Herbert Quick in the World's Work Magazine the following excerpts are taken:

Since Cain first tilled the soil, many a new thing has been seen in agriculture, but in the actual handling of the soil, perhaps not many. A picture of the year's work of the man who without irrigation successfully farms the semi-arid prairies of the "Grat American Desert," however, shows some striking novelties, heralding perhaps an agricultural revolution.

The achievements of Luther Burbank in plant breeding have recently held general attention. I am glad here to put forth the name of Mr. Burbank (at least in the generous emulation of those who are striving to conquer nature)—that of Hardy W. Campbell, a Vermont man who formerly lived in South Dakota and now lives in Lincoln, Neb. The originator of the "Campbell Method" of "Dry Farming," he is teaching the so-called arid west that it is not arid if it but uses properly, ordinary rainfall that its climate yields.

Mr. Campbell, without irrigation, can make crops grow on hundreds of thousands of semi-arid square miles of "desert" that otherwise would be fruitless and flowerless except for the wild growths, sparse and unprofitable, indigenous to such land and climate. In the natural habitat of the cactus, he grows wheat, corn, and vegetables. Between the Missouri river and the mountains, "dry farming" has become a phase of hope.

The Campbell method has fought its way to acceptance through its results only. Its first victory was won in 1894 in Brown county, S. D., when Mr. Campbell grew 142 bushels of potatoes per acre in competition with his unconverted neighbors, who undertook by old methods to surpass the new way, and met failure from severe drought. In the autumn Mr. Campbell's field was moist to a depth of six feet, though all others were dry as dust to an indefinite depth. In October, 1895, the same field showed ten feet of moisture—a clear evidence of gain on the drouth.

Mr.Campbell was testing his system patiently, and by true scientific methods, and this year sent many test tubes of earth to the department of Agriculture at Washington for moisture tests. The following table shows the results of these tests from two fields: No. 1, under the Campbell method; No. 2, under ordinary tillage. Similar results are found in all these tests. The table covers the first ten tests of July, at the Hastings, Neb., station.

Date	Ins. rainfall	Percentage of moisture No. 1	No. 2
July 1st,	None,	18.49	9.71
" 3d,	"	18.30	9.68
" 4th,	"	18.30	10.25
" 5th,	"	19.89	9.16
" 6th,	"	19.19	10.33
" 7th,	"	17.04	9.85
" 8th,	1–16 inch,	18.85	10.00
" 9th,	None,	18.37	8.62
" 10th,	"	17.36	8.90
" 11th,	"	16.29	8.23

The significant thing shown in this table is the uniform moisture of the Campbell fields, at the level most favorable

to plant growth, as well as its constant excess over the others. The writer has found the soil in Campbell's fields moist enough to be squeezed into a ball, while identical soil fifty feet away, cultivated by ordinary methods, would blow away in dust when released.

The Campbell method is spoken of as the salvation of the dry belt. The work is an enormous one, that of changing the traditional methods of plowing and harrowing and tilling of a whole farming population. The wonder is, not that his progress has been so slow, but that in the ten years of his active apostolate (for such his life has been) this useful and patient man has accomplished so much.

RESULTS DECLARED TO BE REMARKABLE.

William E. Curtis, traveler and author, went to Hill City, Kansas, in the summer of 1905, and from there wrote a two-column article for the Chicago Record-Herald in which he said:

What is known as the Campbell method of "dry farming" is being practiced on the semi-arid plains of western Kansas and eastern Colorado with remarkable success. The results accomplished on several model farms, under the direction of the inventor, discoverer or promoter—whichever you prefer to call him—are remarkable, and are entitled to the respect of every one who is interested in the development of the high, dry plains between the Rocky mountains and the Missouri river.

Any one who has doubts of the practicability of the Campbell system should go to Hill City, Kansas, and compare the crops on the Pomeroy farm with those upon the farms which surround it, for the fields of wheat, corn, oats, potatoes and everything else that is growing will be four or five times as great as will be the harvest on the other side of the fences.

Mr. Campbell has been working in North Dakota, South Dakota, Nebraska and Kansas, for twenty years or more trying to induce farmers to adopt his plan of "soil culture," as he calls it, and everywhere he has been, from the James river in the north to the Arkansas, he has been equally successful in producing without irrigation the same results that are usally expected with irrigation with comparatively little more expense. There is no secret about it. The whole thing is simply the exercise of care and patience, and any man of ordinary intelligence can work it as well as a college professor could if he only learns how.

The Pomeroy farm certainly proves the truth of Mr. Campbell's theories, or else he is a wizard. The orchard, five years old, is equal to any I have ever seen; the hedges that divide the fields and surround the garden are as high as the head of a man; the vegetable garden, the berry bushes, the flowers and the foliage are equal to any that you can find upon the best irrigated farm in California; while the wheat, corn and potatoes are simply perfect.

The farm across the road looks skinny and shabby; the gaps between the rows of corn; the bald spots in the wheat, and the feeble poatoes look as if a conspiracy had been set up to furnish as striking a contrast as possible. From one field as Mr. Campbell says, he expects to harvest fifty-six bushels of wheat to the acre by his system. On the other side of the fence, where the ordinary methods have been used, it will not pan out more than seven or eight bushels, and it is the same soil and the same rainfall.

ESSENTIALLY SCIENTIFIC FARMING.

John L. Cowan, writing in the Century Magazine for July, 1906, gave something of what had been done, and he said:

It has been demonstrated on many model farms maintained by western railroads and on hundreds of private farms, that all that is necessary on the plains and in the inter-mountain parks and valleys is intelligently to make the most of the rains and snows that fall in order to grow as good crops as can be raised anywhere. In other words, farming methods must be adapted to natural conditions. This seems so simple and self-evident that the only wonder that men have been so slow in finding it out. It ought not to be hard to believe that lands that produce the rich buffalo and grama grasses of the plains without cultivation, can be made to produce crops still more valuable with cultivation adapted to the soil and climate.

However, what the National Department of Agriculture, the various state governmnts, and the great railroad corporations have at last been made to see, has been demonstrated every season for twenty years consecutive by Mr. H. W. Campbell, of Lincoln, Nebraska, the pioneer "dry farmer" of arid America. In scores of places from the James river to the Arkansas he has been uniformly successful in producing without irrigation the same results that are expected with irrigation, with comparatively little additional expense, but not without more watchfulness and care. What western people have become accustomed to calling the "Campbell system of dry farming" consists simply in the exercise of intelligence, care, patience, and industry.

Dry farming is essentially scientific farming, and for that reason the term used by Mr. Campbell, "scientific soil culture," is perhaps, more truly descriptive than the popular term. Nevertheless, its principles can be, and are applied just as successfully by men who have as little of the education of the schools as they are by the college grad-

uates. However, no farmer in the arid belt need hope for even moderate success without unceasing diligence.

Twenty years ago Mr. J. P. Pomeroy, now of Colorado Springs, acquired 30,000 acres of land in Graham county, western Kansas, and founded Hill City almost in the center of the tract. For fourteen years portions of this tract were cultivated by old-fashioned methods. In all that time only one good crop was harvested, that being in a season when the rainfall was abnormally large. He had heard of Mr. Campbell and his system of dry farming and sent for him, telling him to go ahead and show him just what he could do on land on which profitable farming by ordinary methods had proven to be impossible. Mr. Campbell laid out a model farm on the very land that had been tried often with discouraging results. Last season the sixth successive crop was harvested. In the fourteen years in which old-fashioned methods were followed, thirteen failures were scored. In the six years in which the Campbell system has been on trial on the same lands, a crop failure has been unknown. The smallest yield of wheat per acre in that time has been thirty-five bushels, while farmers close by have never obtained more than thirteen bushels per acre, and very rarely even that. The yields of corn, oats, potatoes, alfalfa, berries, small fruits, and vegetables is equal to that obtained from the average irrigated farms around Greeley, Fort Collins, Grand Junction, and other parts of Colorado "under the ditch." On this farm there is also a six-year-old orchard that is in prime condition, the trees being as large as eight-year-old trees in the famous fruit growing district of Palisades. A more complete vindication of all the claims made by the advocates of the practicability of farming on the plains without irrigation could not well be imagined.

CHAPTER XL.

GOOD FARMING AND GOOD MORALS.

Perhaps it is not fair to assert that for the preservation of the morals of a people dependence must be placed entirely on the farming class; but it is not going a bit too far to insist that as between good farming and poor farming there is a difference as wide as the poles are separated in their relation to the morals of the people.

Did you ever pass an old farm, with broken fences overgrown with weeds, with ramshackle sheds and a house with unmended roof, with exposed corn bins, and a few racing hogs browsing along the hedge rows? And if you have, do you not recall that involuntarily you peeked around the corners expecting to find the head of the family in keeping with his surroundings and living a life not at all to be made use of as an example? Of course not every farmer struggling against odds on a half-barren farm is below the standard in methods of living. There may be high thinking and genuine love for all that is best in the world and this amid surroundings not at all congenial. But usually if there is a desire for the better life, there is some sign displayed by which the keen observer may know that conditions are but temporary.

But you pause at the gate near a modest cottage neatly painted, and about the place there is an air of neatness and cleanness and good living, and you expect to find, and usually do find, a family living the happy and contented life.

Now there is nothing that will go so far toward changing the life of a man or of a family to the better things as prosperity. Poverty is a demoralizing influence. Idleness is next of kin to sin. And idleness is closely associated with poor farming. Whatever tends to give the people more of the material comforts of life helps to raise them up. It is easier to be good when one has had a fine dinner.

Scientific soil culture points the way to greater prosperity on the farm. It means steady large results with no losses. It means that farming operations are reduced to a science. With an understanding of its principles and such application of the same as to produce the results which are always possible, it means the raising of the average of living to a higher plane. It means more home comforts, better farm equipment, finer houses and barns, good roads, telephone, and trolley lines, and above all else support of the schools and the churches.

It is a most excellent thing for any community to give support to the schools and the churches. The benefits come in many ways. They are not all visionary. And a people who do support schools and churches are not the up-grade at all times. They help to better conditions in the cities and towns. They give to the cities the ablest of the men in all walks of life. But unless there is actual success in farm operations the influence nay be the other way. Discontent on the farm is a dangerous thing and has sent many a noble boy and girl to the city with high hopes of betterment which too often have proved a bitter failure.

It is because of the fact that the state and the nation are vitally interested in the welfare of the farming population that public sentiment supports with hearty unanimity the expenditures of millions annually to improve the farming conditions. The state cannot be a good state

unless its people are prosperous and contented. They need not be stupidly content with the idea that they have attained perfection, but they should have the content which comes to him who triumphs in what he undertakes. And so state and nation are alike lending a helping hand to the farmer.

As a great moral influence we shall claim for scientific soil culture a place in the front rank. It leads all others because upon the quality and quantity of what is grown from the soil depends the magnitude and success of all branches of agricultural pursuits.

Fair Investigation.—Agriculture demands and deserves all the investigation which is being given to it—it is in need of, and is worthy of, all the investigators whose services are being devoted to this greatest of all our industries; but let us remember that it is only a genius who can draw correct conclusions from incomplete date or insufficient premises; that we are to use all obtainable information to guide us, and that we are to work together as a unit for the betterment of American agriculture. The work is greater than any man or any office. Let every man develop and magnify the line of work which he is called upon to perform, but let us neither decry nor ignore nor underestimate the value of any other good work. Prof. Cyril G. Hopkins, Illinois University.

CHAPTER XLI.

PROFIT OF SCIENTIFIC SOIL CULTURE

The only way to determine just how profitable scientific soil culture is as compared with the old way is to make the test on the farm but we give here a 2-year comparison as a help to those who want to know the difference. The simple and direct application of scientific soil culture involves one crop in two years. This is not always the case, for it may be two crops in three years or three in four. But assuming that to get ideal results it is necessary to grow just one crop in two years, we may then compare this with two ordinary crops in the same two years and reach a conclusion that will mean something.

We give below a fair estimate of the cost, results and profits of a 2-year period under the scientific method and the old way. Average prices are paid for labor in both cases and we have tried to be conservative. It may be felt by some that we have placed the wheat yield too high under the scientific method, but we have really discounted actual results and made allowance for imperfections.

Wheat yields in the dry country have been, under the Campbell method, as much as 60 to 67 bushels to the acre. We have figured on 50 bushels. But even if this should be cut materially there still is margin for a nice profit. All will depend upon whether or not the work is rightly done. We give a fair estimate on the cost and profits of two fields of 100 acres each, one by the old method and one by the Campbell method as follows:

BY SCIENTIFIC SOIL CULTURE.

Double disking in July, one man, four horses, 45c an acre	$45.00
Harrowing twice over after rains, 10c per acre each time	20.00
Double disking in early spring	45.00
Harrowing three times after rains	30.00
Plowing 7 inches deep in July	200.00
Subsurface packing, once over	25.00
Harrowing four times after rains	60.00
Seeding with drills	40.00
Thirty-four bushels seed wheat at $1	34.00
Harrowing twice in spring with lever harrow	20.00
Harvesting	60.00
Four hundred pounds twine at 14c	56.00
Threshing 5000 bushels at 7c	350.00
Marketing, 3c	150.00
Total expenses two years	$1,135.00
Credit by 5000 bushels at 80c	$4,000.00
Less total expenses	1,135.00
Profit	$2,865.00

BY ORDINARY METHOD.

Plowing in August and September	$200.00
Harrowing once	10.00
Seeding	40.00
One hundred bushels seed	100.00
Harvesting	60.00
One hundred fifty pounds twine, 14c	21.00
Threshing 1300 bushels 7c	91.00
Marketing, 3c	39.00
Total expenses first year	$561.00
Same for two years	1,122.00
Yield first year 1300 bushels at 80c	1,040.00
Yield second 1300 bushels at 80c	1,040.00
Total income for two years	$2,080.00
Total expense two years	1,122.00
Profit	$958.00

Net profit Campbell method one crop in two years	$2,865.00
Net profit old method two crops in two years	958.00
Difference in favor of Scientific Soil Culture	$1,907.00

CHAPTER XLII.

CORRESPONDENCE AND COMMENT.

Under date of July 5, 1906, Charles F. Mills, editor of the Farm and Home, Springfield, Ill., in acknowledging receipt of a copy of the 1905 Manual, wrote:

"My attention was called to your methods of dry farming in the July issue of the Century. We hope to be able to send you some orders for your Manual which will be offered as a premium. Your work is deserving of the highest commendation."

FINEST EVER.

F. H. Oberthier, secretary and general manager of the Comanche Cotton Oil Company, Comanche, Texas, wrote:

"I have read and reread your Manual and I think it is the finest work of the kind I ever saw. I think every farmer in the semi-arid west should study this book. I wouldn't take $1,000 for what it has taught me."

INCREASED LAND VALUE.

Herman S. Youtsey, writing from Fort Collins, Col., Dec. 10th, 1905, said:

"I have been reading what one of the wiseacres has to say in defining the Campbell system of soil culture and as usual the most conspicuous point in the article is what he don't know about the system. Meeting so many articles of this character in which improper notions are inculcated and knowing the importance of a correct knowledge of

the Campbell methods, I am led to the conclusion that some more effective plan of getting your Manual of soil culture into the hands of the people should be devised. I have frequently said that your Manual is worth its weight in gold to any man who tills the soil whether he farms wthout irrigation or with it. No reasonable consideration could induce me to part with the knowledge I have gained from your writing, if such a thing was possible, for by following in the way you have indicated I have caused land costing $3.00 an acre to yield a net income of $18.00 an acre in one year and aside from the question of a monetary consideration, it has lifted farm labor from mere drudgery to the field of scientific pursuit."

GREAT DISCOVERY.

John E. Leet, after years of careful study of the subject, wrote in the Denver Republican:

"The Campbell system is a glorious success. It is not a mere wet season humbug, destined to collapse with the next series of dry years. I have doubted, watched, investigated constantly, for nine months, and have become absolutely convinced that it is the greatest agricultural discovery of recent history. It will rapidly settle the fertile, sunny, beautiful healthful rolling plains of eastern Colorado and western Kansas with a dense and thrifty population."

WEALTH INCREASED.

L. J. Clinton, director of the Agricultural experiment station at Storrs, Conn., writing January 21, 1907, in regard to the Manual, said:

"I know something of the work you have done in reclaiming what was known formerly as 'the great American desert,' and I believe as a result of your instruction in soil

culture work that the wealth of the country has been very materially increased. I shall await the arrival of your book with considerable interest."

IN SOUTH DAKOTA.

R. J. Mann, president of the Clark county National Bank, at Clark, S. D., ordered for free distribution among his bank customers 500 of the Campbell Soil Culture Almanacs, issued in 1907, and he wrote:

"I have been studying your literature the last year and am very much interested in it, and this is the cause of my ordering these almanacs. I know, or believe, you are doing a good work and would be glad to see your work go into the farmers' hands, and I hope that distributing these almanacs will prove what you feel and that I believe can be done in this country with good farming."

W. M. Wiley, manager of the Arkansas Valley Sugar Beet and Irrigated land company, at Holly, Col., writing to Mr. Campbell, said:

"Although I have never met you I have become greatly impressed with what is called the Campbell system of farming. In 1902 we had to farm the lands under the Amity canal without water, and by carrying out a modified system of your views we succeeded in making a crop practically without irrigation, and it was a good crop, too. This served to attract my attention more than ever to your system. I have told several officials of the Santa Fe Railroad that the arid west could be better and sooner put into cultivation by following your theories or the practices recommended by you than by getting the government to spend oceans of money for irrigation works, because no matter how much money was spent in irrigation, the amount of land which the water would cover must necessarily be

infinitesmal compared to the vast area to be cultivated; but that if they would adopt your plan and establish some model farms under your direction something could be done in cultivating the country. I should like very much to meet and have a talk with you. I should like particularly to get the U. S. government interested in your methods."

BIG RESULTS.

J. P. Pomeroy, of Colorado Springs, under date of September 10, 1904, writes to C. E. Wantland, Denver: "We cultivate entirely under Professor Campbell's plan. This season the wheat crop in our section was practically a failure, which was the result of the failure of our farmers to put in their crops in time, and to properly cultivate; this was clearly proven by the fact that on our farm we raised over forty bushels per acre; and from less than one-half bushel of seed planted. Surely the time must soon come, when our people will have realized that this system absolutely assures the production of regular crops every year through western Kansas and Nebraska, as well as eastern Colorado."

The Campbell method is spoken of as the salvation of the dry belt. The work is an enormous one, that of changing the traditional methods of plowing and harrowing and tilling, of a whole farming population. The wonder is, not that his progress has been so slow, but that in the ten years of his active apostolate (for such his life has been) this useful and patient man has succeeded in doing so much.—Herbert Quick, in World's Work.

CHAPTER XLIII.

TOOLS FOR THE FARM.

Since publishing our first manual in 1901, we have been asked many times for a list of the implements we consider best adapted to general farming on the prairie of the great semi-arid belt. This, we realize, is a delicate subject on which to give advice, therefore, we simply give a list of such tools as we bought for the Pomeroy Model Farm at Hill City, the Burlington Model farm at Holdredge and for other farms.

For ordinary sized farms we have four-horse tools, or larger, as far as it is possible. To decrease the cost of production adds profits, the same as to increase the yield. When one man can turn over two fourteen-inch furrows or twenty-eight inches by driving four horses instead of sixteen inches by driving three horses, you are not only decreasing the cost of plowing over thirty per cent, but are getting a field plowed in six days that would take ten days with the sixteen inch plow. This is an advantage in many ways and what is true of plowing is proportionately true of all other farm work.

The following tools make a very complete outfit for four good heavy work horses, and with these horses and tools eighty to one hundred acres can be handled by our plan on the high level priries of the more arid portions of the semi-arid belt where the soils are of the usual sand-loam formation.

LIST OF TOOLS.

One gang plow, two fourteen-inch.
One four-horse disk harrow.
One four-horse improved harrow.
One four-horse combination weeder.
One four-horse Campbell sub-packer.
One two-row cultivator.
One one-horse cultivator.

In addition to these tools comes such planters' drills and harvesters as shall be needed for the crops the farmer may wish to raise.

The list of tools is such as has been found most desirable for securing the best possible physical condition of the soil at the least expense.

THE SUB-SURFACE PACKER.

There are few farm implements of high merit that have had the struggle for recognition that the sub-surface packer has. It was first put upon the market in 1895 and about 100 sold. A few more sold each succeeding year, but no great numbers until the year 1905.

The principal drawback was the fact that it was a new tool, with a new mission, backed by a new principle, and every conceivable theory has been advanced to sidetrack its popularity mainly on the ground that the ideal physical condition brought out by its proper use was not necessary, and as the machine cost from $25.00 to $45.00 according to size and distance from factory, the public generally were quite inclined to credit all theories of the skeptics.

But the machine kept persistently at its mission, proving the marvelous results to be gained from the new principles involved, thereby steadily gaining recognition until

the year 1905, when there were more sub-surface packers sold than in all the previons nine years combined. Then the factory was compelled to expand its facilities and the demand continued to increase until the sales for the year 1906 were equivalent to more than twice the total number sold not only in 1905 but from January 1st, 1895, to January 1st, 1906. Just before going to press we learn that the orders received at the factory for the month of January, 1907, were nearly half as many as the entire sales for 1906.

There is but one reason for this enormous increase in the sales of the sub-surface packer, and that is, that this new machine has accomplished its new mission by proving through practical demonstrations that the new principle of a thoroughly pulverized and absolutely firm sub-stratum, or root and seed bed, and its perfect connection with the subsoil below, is one of the most vital conditions for successful crop growing, and the one point to be fully recognized in preparing the soil for the purpose of growing large yields of all kinds of cereals.

An unassuming fellow townsman of mine, Mr. H. W Campbell, has made a discovery worthy to rank him with Watt, Hudson, Eli Whitney and Edison—that of so storing up water in the soil to be cultivated as to make a very meager precipitation suffice to grow a crop and that with no irrigation.—E. Benjamin Andrews, Chancellor Nebraska State University.

CHAPTER XLIV.

SOME HISTORY OF THE MOVEMENT.

The Northwestern Miller, in issues in November, 1906, contained three very complete and satisfactory articles upon the Campbell system written by John L. Cowan, in which an outside view of the work was given, and from the standpoint of an investigator coming to the subject without prejudice. Below is given some portions of this largely for the bit of history which Mr. Cowan wove into the narrative:

There has been no more important agricultural development within recent years than the sudden rise in popular approval of the Campbell System of Scientific Soil Culture —or, as the public prefers to call it, "Dry Farming." During two months of the past summer, it was given more magazine and newspaper publicity than in the twenty years before, through which the originator of the system toiled to bring it to perfection and fought for recognition.

The one thing that has finally compelled endorsement is its results. It has "delivered the goods," and few people will refuse to credit the evidence of their own senses. Consequently, the great trans-continental railroad systems owning land grants have vied with ten thousand land agents in their efforts to inform the public about this new system of farming on the "dry lands" without irrigation.

The National Department of Agriculture and the various state agricultural colleges have not endorsed or given official recognition to the Campbell system. They have

recognized its results, if not in official documents, in the far more significant form of establishing numerous experiment stations on the high, dry plains that they have always hitherto regarded as hopelessly arid. There they are demonstrating along independent lines the very facts to the proving of which Hardy W. Campbell has devoted more than twenty years of his life. This belated government action, taken when the results of the Campbell system could no longer be denied or ignored, is, in fact, the strongest endorsement that the Campbell system of farming without irrigation in the semi-arid region could receive. * *

Mr. Campbell's own account of the circumstances that started his investigations is interesting, and hitherto unpublished. In 1882, he harvested one of the greatest wheat crops that had ever been cut and threshed in the Dakotas, obtaining 12,000 bushels from 300 acres of land, in Brown county, South Dakota. The next year, his crop of 260 acres of the same land was an absolute failure, while the remaining 40 acres returned a good yield. Here was a puzzling proposition, as all the land had received the same treatment and had been seeded at practically the same time. To discover the reason for the widely differing harvests became, for a time, Mr. Campbell's ruling passion.

He recalled that the record-breaking crop of 12,000 bushels had been secured after spring plowing of the land. Also that the 260 acres that failed to yield a crop worth harvesting the subsequent season had been plowed in the fall, while the 40 acres from which a good crop had been obtained had been plowed in the spring. The conclusion seemed inevitable that the secret of obtaining good crops lay in the spring plowing.

He talked it over with his neighbors, and everyone agreed that the virtues of spring plowing for spring wheat

had been incontrovertibly demonstrated. Fortunately for the farmers of Brown county, they realized that it would be impossible for them to plow all their wheat land in the spring in time to get their seeding done: but everyone reduced the amount of fall plowing to its lowest possible terms. Never before or since was the percentage of wheat land in that neighborhood plowed in the spring so great. When harvest time came, everyone had the same result: the crop was all but a total failure on the land that had been plowed in the spring; but that plowed the preceding fall returned a good yield.

Campbell, the man from Vermont, where people are born asking questions, and never outgrow the habit, was not discouraged. He was willing to admit, with his neighbors, that the whole secret of the production of good crops did not lie in the time of plowing. Where he differed from his neighbors was in his refusal to believe that the secret was past finding out.

Even at that early stage of his investigations, he believed it possible to conserve in the soil sufficient moisture to mature a crop, even in years of extreme drouth such as brought disaster to the farmers of the plains with discouraging frequency. The problem to be worked out was how to place the soil in the proper physical condition for the reception and storage of moisture. For the reception and ready percolation of moisture, it required no extended train of reasoning to teach him that the soil must be kept loose and porous by thorough cultivation.

How to keep the moisture there, was a widely different matter. The common expedient was the use of the roller, in order to compact the soil and prevent too rapid evaporation. Experiment convinced him that this was of little value, because its effects were confined to two or three

inches of top soil. Further experiment showed him that it defeated the very end it was designed to promote, increasing the movement of moisture from below up into the compacted stratum, where it speedily passed off by evaporation. While perfectly true that a plowed field that has been rolled shows the presence of considerably more moisture near the surface that can be found in one that is due solely to the exhaustion of the supply that has percolated down into the subsoil. That supply is needed far more urgently to carry the growing crop over the protracted heat and probable drouth of summer than to aid in the germination of seed. The use of the roller, therefore, was abandoned, as promoting the early exhaustion rather than the conservation of moisture.

In 1885, he designed his first sub-soil packer, constructed somewhat after the form of a grain drill, with teeth, or packing devices that slanted backward, penetrating the soil to a depth of several inches, tending to squeeze the earth between them closer together. This gave encouraging results as a crop producer, and frequent tests of the soil, compared with tests of adjacent lands not thus packed, proved that it did conserve the moisture, although not as efficiently as was desirable. The use of this implement proved impracticable, for the reason that the friction was too great and it required too much power to work it to render it adaptable for general farm use. Nevertheless, the experiments made with it were of great value, proving that the packing of the sub-soil (not of the surface) would conserve the moisture.

To give the record of the hundreds of experiments that have been conducted since 1885 would not now be possible. Even if possible, that record would be tedious, uninteresting and unimportant. Equally unimportant would be an

account of his efforts to remedy the defects in his early education that so seriously hampered him in the prosecution of a strictly scientific investigation along original lines. Many of the things that he had to learn by patient experiment would have been taught him by the schools, or could have been reasoned out had he been thoroughly grounded at the start in scientific methods. Perhaps, however, if his idea had been conventionalized by too much of the science of college curricula he might have accepted the dictum that the reclamation of the semi-arid lands was impossible, and the Campbell system would never have been born.

After giving much more of the detail history of the years of labor which resulted in the development of the system Mr. Cowan continued:

Some have gone so far as to assert that most of the methods taught by Mr. Campbell were advocated by Jethro Tull, a hundred and twenty-five years ago. Inasmuch as Jethro Tull never visited America and probably never heard of the American plains, it would be remarkable indeed if he had devised a system of agricultural procedure suited to conditions there.

It is, of course, true that many of the facts of the Campbell system were known long before Mr. Campbell's time. Some of the methods used are applicable to farming the whole world over, and have been practiced for generations. Some of the processes have been worked out under the pressure of necessity by hundreds, or perhaps, thousands, of farmers on the plains. If Campbell had done no more than collect, organize and classify these disconnected facts and methods into a coherrent system of practice adapted to conditions in the semi-arid belt, he would have accomplished a work of the very highest utility.

He has done much more than that. He has adopted

nothing on mere hearsay or authority. Every principle advocated by him, he has tested, not once, nor in one place, but many times, in widely separated localities, in seasons of greatly differing rainfall and temperature, throughout the plains region from the James river valley to the Texas Panhandle. In addition, there are principles of soil culture and methods of procedure that unquestionably originated with him. One of these is that of "summer culture" on newly broken prairie land, before any attempt is made to grow a crop. Anyone who breaks prairie lands, and plants them without first devoting a full season to careful cultivation in order to get the soil in the proper physical condition for the promotion of plant growth, and in order to store a sufficient amount of moisture within reach of the plant roots to carry the growing crop through a protracted drouth, is simply inviting failure should a season of unusual drouth follow.

Another feature that originated with Mr. Campbell, which he regards of vital importance, is the sub-soil packer. This is an absolutely new farming implement, the essential feature consists of a series of sharp, wedge-shaped wheels, that cut into the ground, and literally wedge the portions between them together.

These wheels exert both a lateral and a downward pressure, accomplishing a number of desirable results. They elimnate the air spaces left by overturning the furrow slice along the bottom and the sides of preceding furrows; press the earth firmly around the weeds, clods and stubble; aid in pulverizing the soil, thus increasing its capillary attraction and its water-holding capacity; and, at the same time, they leave the surface soil loose and in condition to prevent unnecessary loss of moisture through evaporation.

CHAPTER XLV.

CORRESPONDENCE COURSES OF STUDY.

There has not been any development in educational lines in recent years to equal in extent and importance that which relates to the use of correspondence or mail courses of study. Every one has become familiar with the mail order mercantile house which is prepared to do business with the individual consumer anywhere in the country. The mail routes of Uncle Sam reach into every settlement of the country. They cover the vast prairies as well as penetrate into the deep woods of the timbered regions. The facilities for communication between people are not better for the residents of the cities than for the residents of the country. Great mercantile houses have taken advantage of this to establish communication with consumers direct, to sell to them direct, and to transact all their business by mail. There is some prejudice against this because of the unquestioned fact that here is a form of competition that is injurious to local business and therefore retards rather than aids in building up local trading communities. But the mail order business is a reality.

Another extension of this same work and we have the correspondence course of study. By and through private enterprise this plan has grown to great proportions in recent years. There are correspondence courses in nearly everything. They teach science, literature, art, trades, mechanics, chemistry, pharmacy, bookkeeping, surveying, draughtng, engineering, writing, weaving, electricity, etc. As a

result of this work it has been placed within the reach of thousands of boys and girls to secure special education they desire without the great expense of attending some school or college in a distant city. The son of a poor mechanic struggling for a living in a city factory becomes ambitious to learn a useful trade or science, and his only time is that which most boys use for play-time. But his ambition leads him to take up a correspondence course of study, and in the long evenings at home he pores over these books until he has mastered his subject. The result is that a great engineer, or inventor, or contractor, or business man is developed. No matter how many great colleges or universities might have been founded, this development of the poor boy who must labor while he learns would never have been possible but for the correspondence course.

The theory of the correspondence course system is the taking of the school into the home. It is not possible for any great proportion of the ambitious boys and girls of the country to take advantage of our schools of higher education. To many millions of them it is denied because of various circumstances. They have not the time, they have have not the preliminary preparation, they cannot afford it, they do not know how to get into the colleges. These shut-out boys and girls are just as important to the country as those for whom the college doors open. The correspondence course of study takes the college right to these boys and girls. It opens the way for higher education to millions who would otherwise have no such opportunity.

So valuable is this principle that it is receiving state recognition. Much of the development of the correspondence course plan is due to private enterprise. All honor to those who have been pioneers in this work. But it has been taken up by such public institutions as for instance,

the Armour Institute, of Chicago, in recognition of the fact that it ought to be largely a public work. It is being taken up by the great agricultural and industrial colleges of the country. Legislatures are making appropriations for carrying on the work. It is only a matter of time until many of the general branches will be taught in this way under state supervision.

There have been prepared a number of courses in general agriculture, and some of these of great merit. It is a little strange that the one subject which more than any other lends itself readily to the correspondence course idea has been neglected until the last—agriculture. There can be no teaching of agriculture away from the farm. Actual contact with the soil is essential in the teaching of agriculture. No man can learn to farm by poring over books. But if in the poring over books he has opportunity to go out every day and apply in practical way that which he is learning, then much may be learned of great value from the books. It is because of this that a correspondence course in agriculture seems especially appropriate. The farmer is less likely than any other to find opportunity to get away from his work and to take up special courses of study in the colleges. He seldom has the preliminary preparation so that he can get into the agricultural colleges. But he does have some time for study and he generally has the disposition to study and to learn. The correspondence course, when it comes to the farmer, comes to one who can make the greatest possible use of the same.

But most of the correspondence courses as prepared not only by corporations making a specialty of this work but by the colleges and universities, are distinctly intended to take boys and girls from the farms and to put them into the workshops of the cities. It is not very difficult to lead

the farm residents to feel that in some other field of activity the chance of success is better than in their own. That is why the farmers are so often approached with suggestions of learning, through correspondence courses, something that will fit them for other work.

As a matter of fact, the farmer can gain most from a correspondence course with direct relation to his own work. The time has passed for sneering at the so-called book-farmer. The college bred farm superintendent is a reality and a success. Men who are making a study of farming with special reference to well established principles are taking the lead. The average farmer does his work well, and he succeeds fairly well, but as a matter of fact, he might do a little better by knowing some things. He gains a great deal by the study of farm papers and magazines, but he too often treats their advice lightly.

What is needed for the farmer in these days is some method by which there can be brought right home to him all the science and all the achievement of the colleges, the results of special study and investigation, the lessons of innumerable experiments, and to do this in a way that will appeal to him as something practicable. He should be able to gain knowledge of a kind that is useful. No theory should be presented to him without a purpose. Nothing should be given him that has not a practical side. It is well he should understand the science of the soil physics and seed germination and plant development and all that —but he should understand all this with special reference to making his own crops bigger and better. The philosophy of farming is all very well, but the essential thing is to accomplish great results. Now it is entirely possible that through the correspondence course of study method the farmer may be given the essentials of his science in such a

way that he can immediately apply them to the problems just before him. The farmer is in a better position to profit by and through a correspondence course than any other.

The extension of the rural route service has brought every farm in the country up next to the city.

In order to meet the demand for further and more definite instruction in the principles of scientific soil culture there is in preparation a complete correspondence course in agriculture having special reference at all times to this branch of the subject. This work is being prepared by H. W. Campbell, and under his personal direction, and as soon as it is ready for use the fact will be made known to the public. Those who take this correspondence course will have many benefits, such as the advantage of personal correspondence with the editor, the results of scientific investigation and personal and practical instruction.

In this connection a work is now being carried on that is sure to be of the greatest advantage to all persons interested at all in the subject. At the time this is written a number of model or experimental farms are in operation in various states of the west. These are farms on which are being carried on the best principles of scientific tillage under the personal direction of Mr. Campbell. The soil has been fitted in accordance with the most approved methods. All the experience of the past 25 years has been drawn upon to make these farms successful. They are in the hands of competent persons. An exact record is being kept, and the results will be carefully computed. The outcome will be the collection of data regarding scientific tillage that will be invaluable to the farmers of the dry country. At the same time a number of other farms are being opened and secured. The sole object in these farms is to carry on this educational work. They are not operated

for profit nor as a side line for speculative purposes, and they are kept free from the influences that might tend to exaggerate the results for selfish reasons. The persons who take the correspondence course will be the greatest gainers from this educational and demonstrative work.

Since the first edition of this book was printed there has also been started, in response to an almost universal demand, a monthly magazine called Campbell's Scientific Farmer, which is devoted wholly to the teaching of the principles of scientific soil culture. This is not a general farm paper nor a household paper, but a special journal devoted to one line of farming or one branch of agriculture, just as a stock breeder's journal or a horticultural magazine or a publication devoted to forestry or irrigation. This Campbell's Scientific Farmer will therefore supplement the great work in which we have been engaged many years, by carrying direct to the people current information as to what is done and is being done in the various portions of the country with regard to soil culture methods best adapted to the dry country or to dry conditions.

Everywhere it is coming to be recognized that agriculture is a great science and that it is one of the things about which there is always much to learn. The movement back to the farms is genuine, and it has a reason. But if there is to be a movement back to the farms it should be intelligently directed. More than that, the movement should have a solid foundation. In the semi-arid portions of the countries lie the greatest possibilities. Those who make themselves perfectly familiar with every question which may arise in regard to the semi-arid region are those who will achieve greatest success.

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